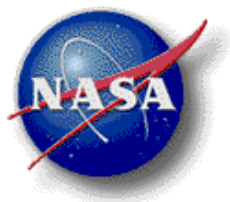


Alpha Magnetic Spectrometer 02 (AMS-02) Experiment/Vacuum Case (VC) Payload Integration Hardware (PIH) Interfaces

Engineering Directorate

February 2009

Revision D



National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

Alpha Magnetic Spectrometer 02 (AMS-02) Experiment/Vacuum Case (VC) Payload Integration Hardware (PIH) Interfaces

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February 2009

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PREFACE

This Interface Control Document (ICD) represents the interface agreement between the Alpha Magnetic Spectrometer – 02 (AMS-02) Experiment and the Vacuum Case Payload Integration Hardware (PIH) for the version of the payload to be operated on the International Space Station (ISS) for a minimum of three (3) years. The mission baseline is 1000 days of operational time (24,000 hours) in full deep space view.

A precursor flight (AMS-01) was accomplished on the Space Shuttle during the STS-91 flight and was addressed in an ICD similar to this document. The AMS on STS-91 was operated for approximately 8.5 days during the flight.

CONTENTS

Section	Page
1.0 INTRODUCTION	1
1.1 General	1
1.2 AMS Payload Description	1
1.3 Document Purpose	2
2.0 MECHANICAL REQUIREMENTS	3
2.1 Coordinate System.....	3
2.2 AMS Experiment to Vacuum Case Interfaces.....	5
2.2.1 Cryomagnet System to Vacuum Case (VC).....	5
2.2.2 Temporary Seal.....	12
2.2.3 Magnet Support System.....	13
2.2.4 Feed-Thru Port Locations.....	19
2.2.5 Plumbing and Electrical Feed-Thru Ports.....	23
2.2.6 Cryocooler Interfaces and Ports.....	25
2.2.7 Cryo Service Port.....	29
2.2.8 Keep In/Out Zones	32
2.2.9 Generic Bolt Pattern Interfaces on Inside of VC.....	46
2.2.10 GSE Holes at Strap Locations	50
2.2.11 Experiment Interfaces to Vacuum Case.....	54
2.2.11.1 Tracker Support Feet.....	54
2.2.11.2 Anti-Coincidence Counter Support Feet	56
2.2.11.3 Generic Bolt Pattern Interfaces on Outside of VC.....	56
2.2.11.4 Anti-Coincidence Counter Photomultiplier Mounts.....	62
2.2.11.5 Thermal Control System Interface to Vacuum Case.....	63
2.2.12 Structural Finish and Flatness.....	55
3.0 ASSEMBLY REQUIREMENTS	64
3.1 Assembly Procedure Between VC and Cold Mass	64
3.1.1 Hardware.....	69

Section	Page
3.1.2 Strap System.....	70
3.2 Assembly Procedure Between VC and ACC.....	74
3.3 Assembly Procedure Between VC and Tracker	75
4.0 VACUUM CASE VACUUM AND PRESSURE TEST REQUIREMENTS.....	76
4.1 Vacuum Test Requirements	76
4.2 Proof Pressure Test Requirements.....	76

TABLES

Table	Page
Provided Hardware Summary	69
Non-Linear Strap Load Data	71

FIGURES

Figure	Page
1.2-1 AMS-02 Payload and Experiment.....	2
2.1-1 AMS-02 Payload and Experiment Coordinate Axis and Origin (1 of 2)..	3
2.1-2 AMS-02 Payload and Experiment Coordinate Axis and Origin (2 of 2)..	4
2.2.1-1 Vacuum Case Assembly (NASA Delivered)	5
2.2.1-2 Vacuum Case Assembly (With Misc. Port Attachments)	6
2.2.1-3 Vacuum Case Upper and Lower Support Rings (With Misc Cryomagnet H/W Attached)	7
2.2.1-4 Vacuum Case Cross-Section	8
2.2.1-5 Inner Joint Detail.....	9
2.2.1-6 Closeout Weld	9
2.2.1-7 Outer Joint Detail.....	10
2.2.1-8 O-Ring Groove Detail	11
2.2.2-1 Temporary Seal	12
2.2.3-1 Support Strap Locations	13
2.2.3-2 Section Thru Strap Port C1W1 (X-direction).....	14
2.2.3-3 Section Thru Strap Port C2W2 (Y-direction).....	15
2.2.3-4 Strap Feed-Thru Detail	16
2.2.3-5 Strap Feed-Thru Face View	17
2.2.3-6 Strap Feed-Thru Detail View	17
2.2.3-7 ISO View of Strap Port	18
2.2.3-8 Strap Closeout Cap (Provided by ETH/SCL).....	18

Figure		Page
2.2.4-1	Plumbing and Electrical Port Locations	20
2.2.4-2	Port Locations – Front ISO View	21
2.2.4-3	Port Locations – Back ISO View.....	22
2.2.5-1	Plumbing/Electrical Port	23
2.2.5-2	Mating Component for Feed Thru Ports	24
2.2.6-1	Cryocooler Port ISO Views.....	26
2.2.6-2	Cryocooler Interfaces and Ports	27
2.2.6.3	Cryocooler Interfaces	28
2.2.7-1	Cryo Service Port	29
2.2.7-2	Cryo Service Port Layout – Front ISO View	30
2.2.7-3	Cryo Service Port Layout – Back ISO View	30
2.2.7-4	Cryo Service Port Layout.....	31
2.2.8-1	Keep In/Out Zones for the Upper Support Ring.....	33
2.2.8-2	Keep In/Out Zones for the Lower Support Ring.....	34
2.2.8-3	Detail View of the Keep Out Zone for the VC/USS-02 Assembly	35
2.2.8-4	Section View of the Keep Out Zone for the VC/USS-02 Assembly	36
2.2.8-5	Keep In Zone for the Cryocoolers.....	37
	Keep in Zone for the Cryo Service Port Top View	38
	Keep in Zone for the Cryo Service Port Side View	38
	Keep in Zone for the Cryo Service Port GSE Top View	39
	Keep in Zone for the Cryo Service Port GSE Side View	40
	Upper Support Ring Magnet Hardware (1 – 5).....	41-43
2.2.8-11	Upper Support Ring Magnet Hardware (1 – 6)	43-45
2.2.9-1	ISO View Section of Generic Holes for CM	46
2.2.9-2	Upper Support Ring Generic Hole Pattern for CM.....	47
2.2.9-3	Lower Support Ring Generic Hole Pattern for CM.....	48
2.2.9-4	Detail Views of Generic Hole Pattern for CM.....	49
2.2.10-1	ISO View of Strap GSE Holes	50

Figure	Page
2.2.10-2 Top/Bottom View of Hole Locations.....	51
2.2.10-3 Section View of Side Hole Locations	52
2.2.10-4 Detail View of Side Holes	53
2.2.11-1 ISO View Showing Experiment Interfaces on Conical Flange	54
2.2.11.1-1 Tracker Mounting Pattern	55
2.2.11.1-2 Tracker Mounting Cross-Section	55
2.2.11.2-1 ACC Mounting Pattern.....	56
2.2.11.3-1 Generic Bolt Hole Pattern on Conical Flange Ribs.....	57
2.2.11.3-2 Generic Bolt Hole Pattern on Vacuum Case	57
2.2.11.3-3 Generic Bolt Hole Pattern on VC Upper Support Ring	58
2.2.11.3-4 Generic Bolt Hole Pattern on VC Outer Cylinder Upper Flange	59
2.2.11.3-5 Generic Bolt Hole Pattern on VC Outer Cylinder Lower Flange	60
2.2.11.3-6 Generic Bolt Hole Pattern on VC Lower Support Ring	61
2.2.11.4-1 ACC PM Mounting Locations	62
2.2.11.4-2 Keep-In Zone for ACC and Tracker Electrical/Plumbing Lines	62
3.1-1 VC/Cold Mass Assembly Procedure.....	64-67
3.1.2-1 Force Versus Deflection for C1W1 Strap - Cold	72
3.1.2-2 Force Versus Deflection for C1W1 Strap - Warm.....	72
3.1.2-3 Force Versus Deflection for C2W2 Strap - Cold	73
3.1.2-4 Force Versus Deflection for C2W2 Strap - Warm.....	73

ACRONYMS AND ABBREVIATIONS

ACC	ANTI-COINCIDENCE COUNTER
AMS	ALPHA MAGNETIC SPECTROMETER
CM	COLD MASS
CMR	COLD MASS REPLICA
DOE	DEPARTMENT OF ENERGY
ESCG	ENGINEERING AND SCIENCES CONTRACT GROUP
ETH	EIDGENOSSISCHE TECHNISCHE HOCHSCHULE
GHE	GROUND HANDLING EQUIPMENT
GSE	GROUND SUPPORT EQUIPMENT
GSFC	GODDARD SPACE FLIGHT CENTER
ICD	INTERFACE CONTROL DOCUMENT
ISS	INTERNATIONAL SPACE STATION
JS	JACOBS SVERDRUP
JSC	LYNDON B. JOHNSON SPACE CENTER
LSR	LOWER SUPPORT RING
MIT	MASSACHUSETTS INSTITUTE OF TECHNOLOGY
NASA	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
PIH	PAYLOAD INTEGRATION HARDWARE
PM	PHOTOMULTIPLIER
SCL	SPACE CRYOMAGNETICS LTD.
SFHe	SUPERFLUID HELIUM
STA	STRUCTURAL TEST ARTICLE
STE	SPECIAL TEST EQUIPMENT
TBD	TO BE DETERMINED
TCS	THERMAL CONTROL SYSTEM
USR	UPPER SUPPORT RING
USS	UNIQUE SUPPORT STRUCTURE
VC	VACUUM CASE

1.0 INTRODUCTION

1.1 General

In this Interface Control Document (ICD) “AMS” will refer to the total complement of activities, hardware, software, test, integration and operation of the Alpha Magnetic Spectrometer – 02 (AMS-02). The flight hardware is referred to as the “AMS Payload” and is comprised of two parts: the “AMS Experiment” provided by the international AMS Experiment Collaboration and the “AMS Payload Integration Hardware (PIH)” provided by the JSC Engineering Directorate with the support of the Engineering and Sciences Contract Group (ESCG).

This ICD pertains only to the version of the AMS (AMS-02) that will be installed and operated on the International Space Station (ISS). The acronym “AMS-01” will be used for references to the precursor flight version that flew on STS-91.

1.2 AMS Payload Description

The AMS Experiment is a state-of-the-art particle physics detector containing a large, cryogenic superfluid helium superconducting magnet that will be designed, constructed, tested and operated by an international team organized under United States Department of Energy (DOE) sponsorship. The AMS Payload is shown in Figure 1.2-1. The AMS Experiment will use the unique environment of space to advance knowledge of the universe and potentially lead to a clearer understanding of the universe’s origin. Specifically, the science objectives of the AMS are to search for cosmic sources of antimatter (i.e., anti-helium or heavier elements) and dark matter.

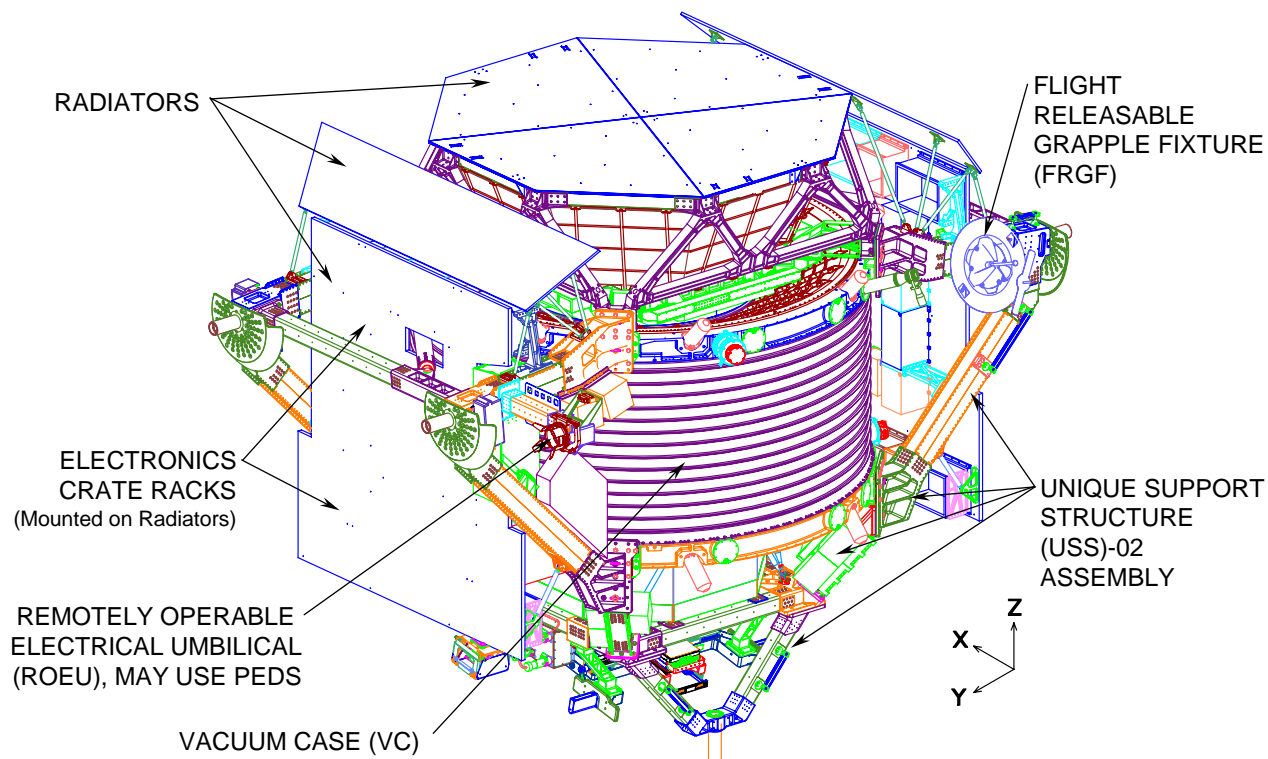


Figure 1.2-1 AMS-02 Payload and Experiment

1.3 Document Purpose

This ICD is only to define the interfaces between the PIH Vacuum Case and the Eidgenössische Technische Hochschule (ETH) Cryomagnet and the AMS-02 Tracker and the Anti-Coincidence Counter (ACC).

2.0 MECHANICAL REQUIREMENTS

This section describes the mechanical and physical interfaces associated with the PIH Vacuum Case, ETH/Space Cryomagnetics Limited (SCL) Cryomagnet and the AMS-02 Tracker and ACC.

2.1 Coordinate System

The AMS-02 payload and AMS-02 experiment coordinate axis systems are identical and are shown in Figures 2.1-1 and 2.1-2. Dimensions are in inches. The AMS-02 origin is at the geometric center of the Vacuum Case and Tracker. All coordinate systems shown in this document are based on the right hand rule.

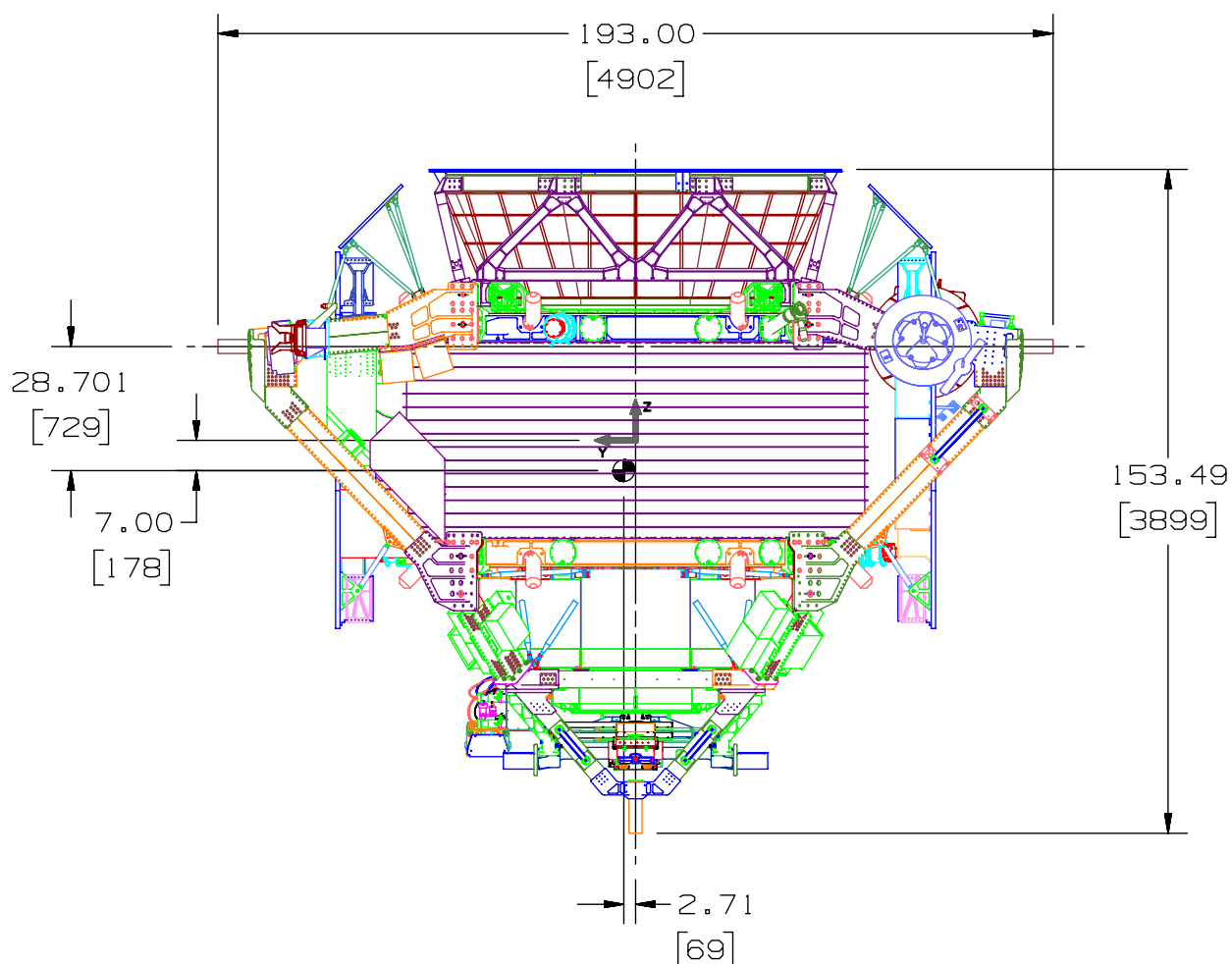


Figure 2.1-1 AMS-02 Payload and Experiment Coordinate Axis and Origin (1 of 2)

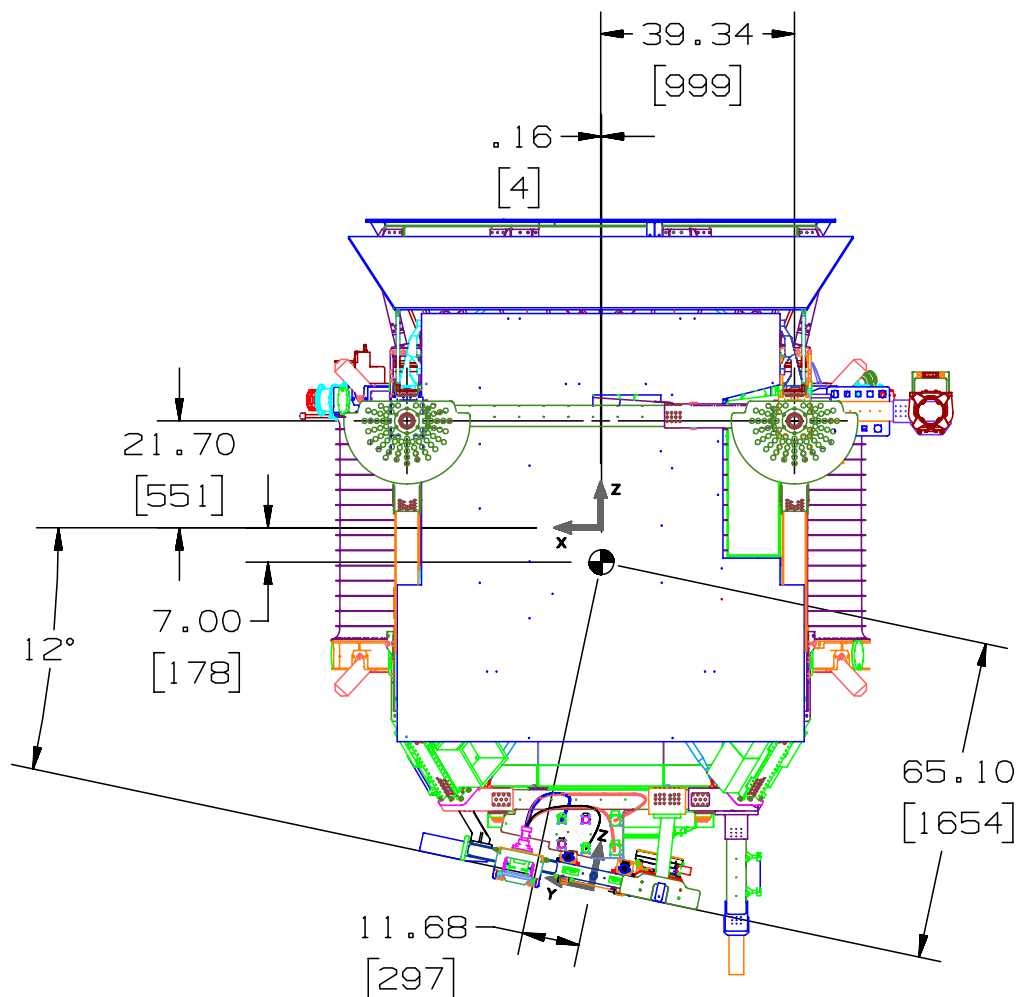


Figure 2.1-2 AMS-02 Payload and Experiment Coordinate Axis and Origin (2 of 2)

2.2 AMS Experiment to Vacuum Case Interfaces

2.2.1 Cryomagnet System to Vacuum Case (VC)

The Cryomagnet Vacuum Case is being developed by NASA/ESCG and will interface to the Cryomagnet, Super Fluid Helium Tank, and a Cryogenic System internally. It will also interface to the Tracker, Anti-Coincidence Counter (ACC), and various other experiment hardware externally. Figure 2.2.1-1 shows the overall Vacuum Case Assembly that will be delivered by NASA and Figures 2.2.1-2 and 2.2.1-3 show the Vacuum Case Assembly and Upper and Lower Support Rings with miscellaneous port attachments. Figure 2.2.1-4 shows a section view of the Vacuum Case Assembly. Details of the inner joint, closeout weld, outer joint, and O-ring grooves are shown in Figures 2.2.1-5 through 2.2.1-8 respectively.

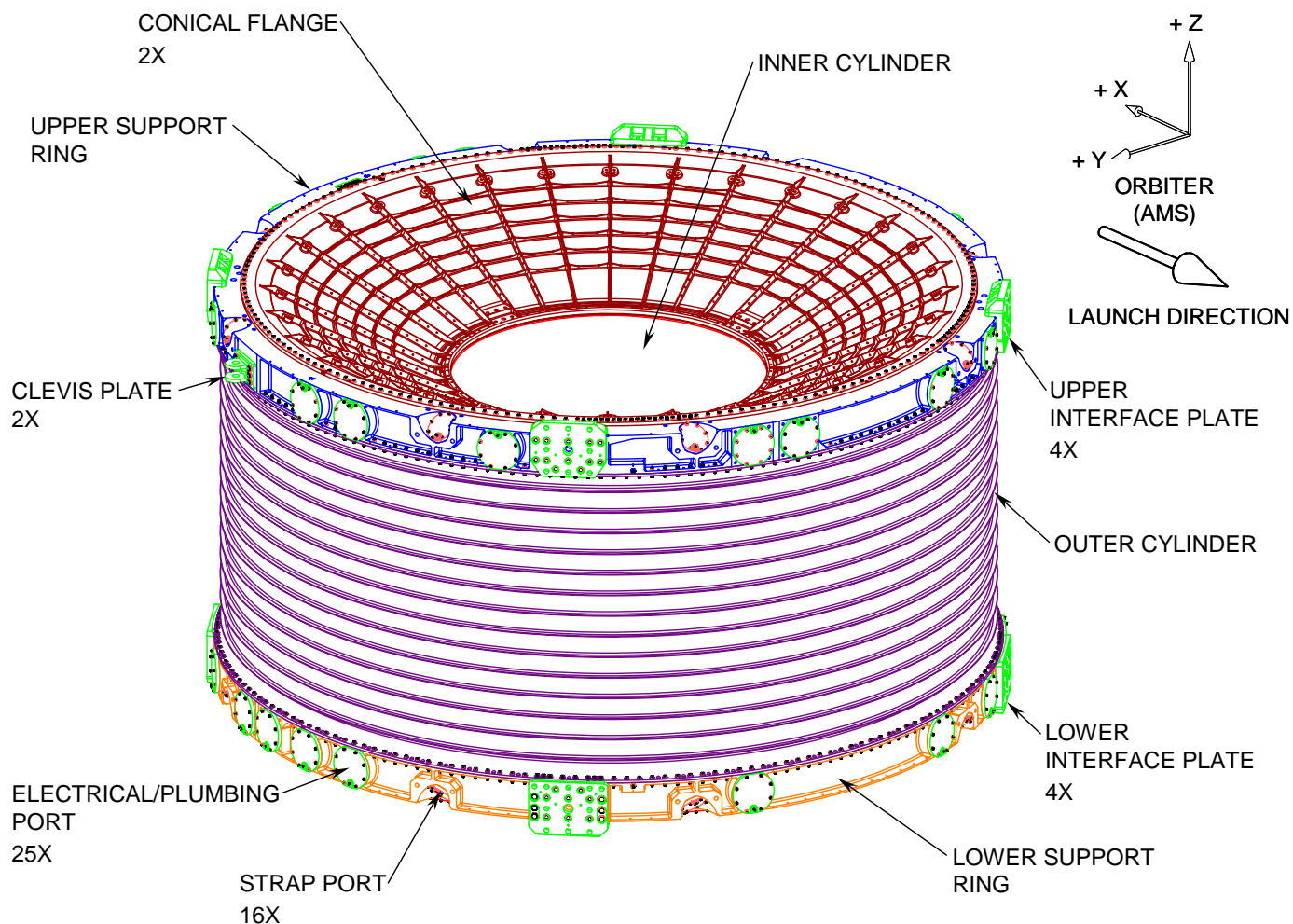


Figure 2.2.1-1 Vacuum Case Assembly (NASA Delivered)

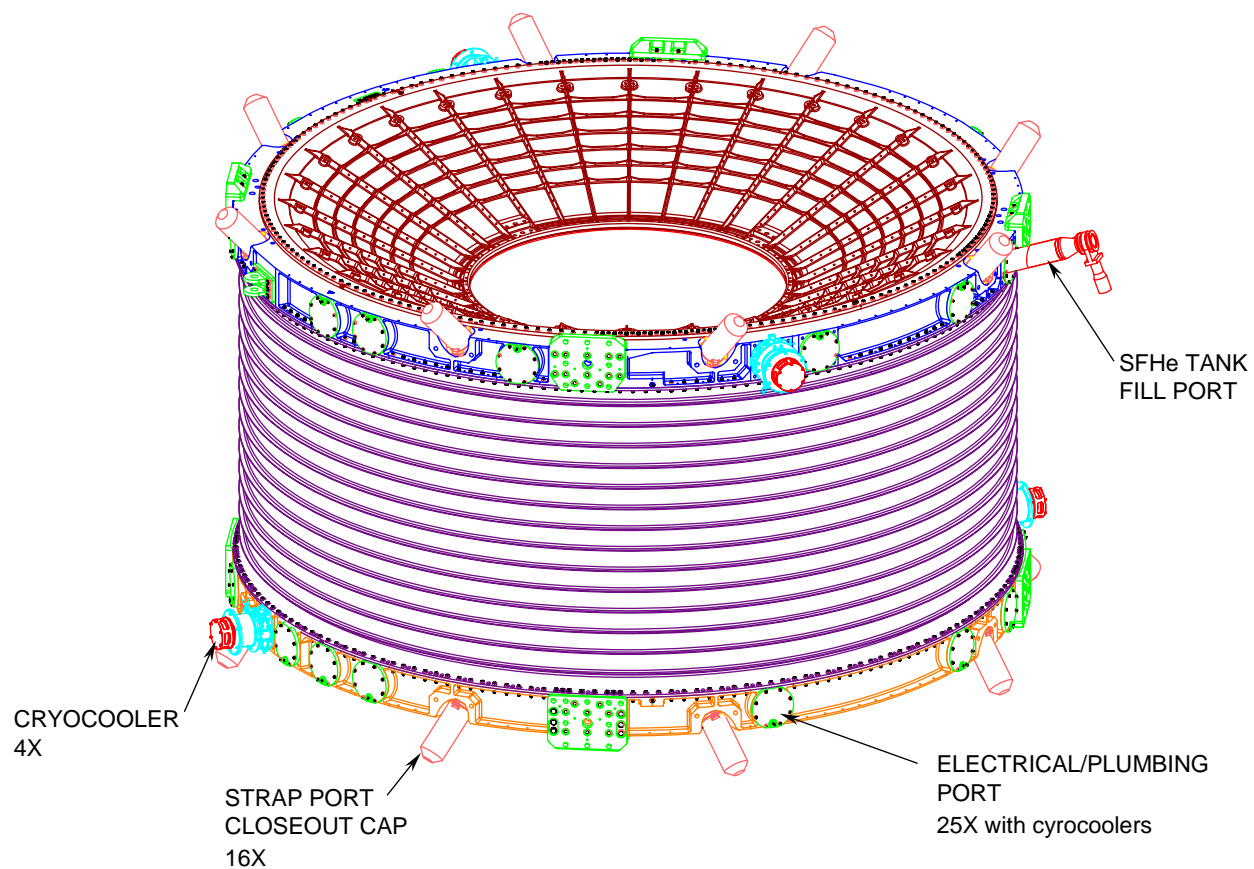
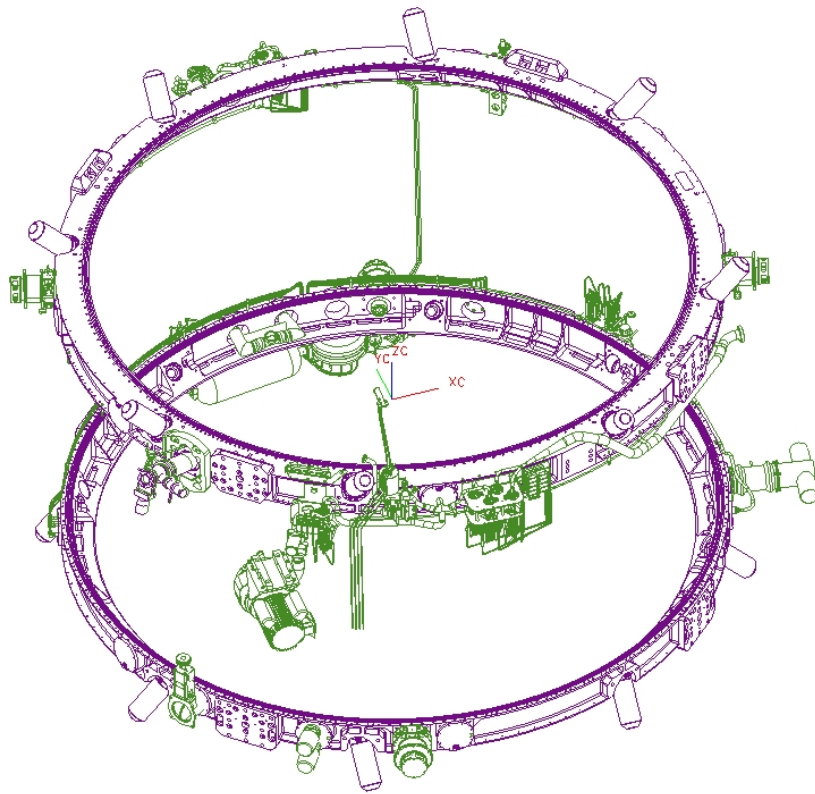


Figure 2.2.1-2 Vacuum Case Assembly (With Misc. Port Attachments)



**Figure 2.2.1-3 Vacuum Case Upper and Lower Support Rings
(With Misc. Cryo Magnet H/W Attached)**

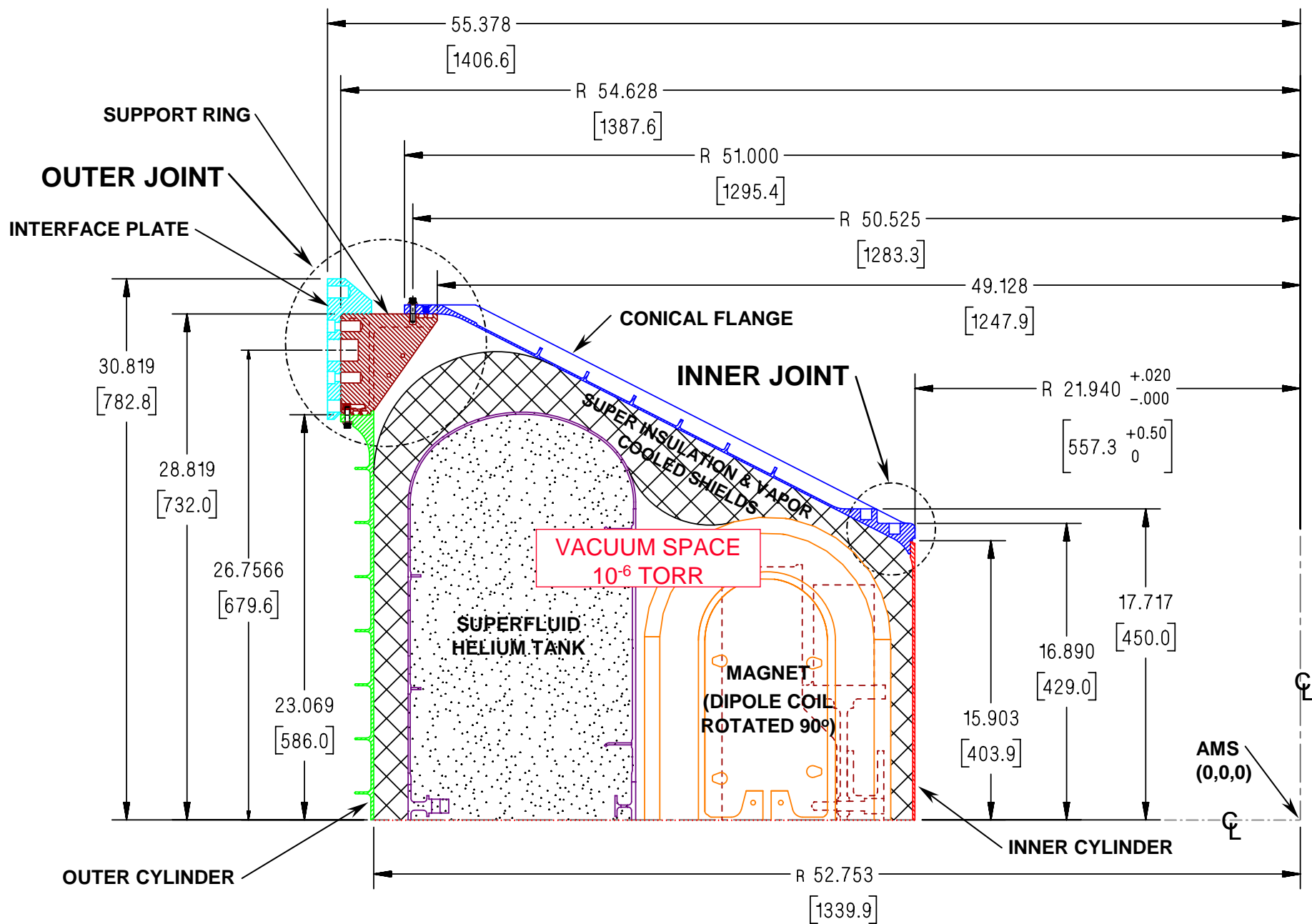


Figure 2.2.1-4 Vacuum Case Cross-Section

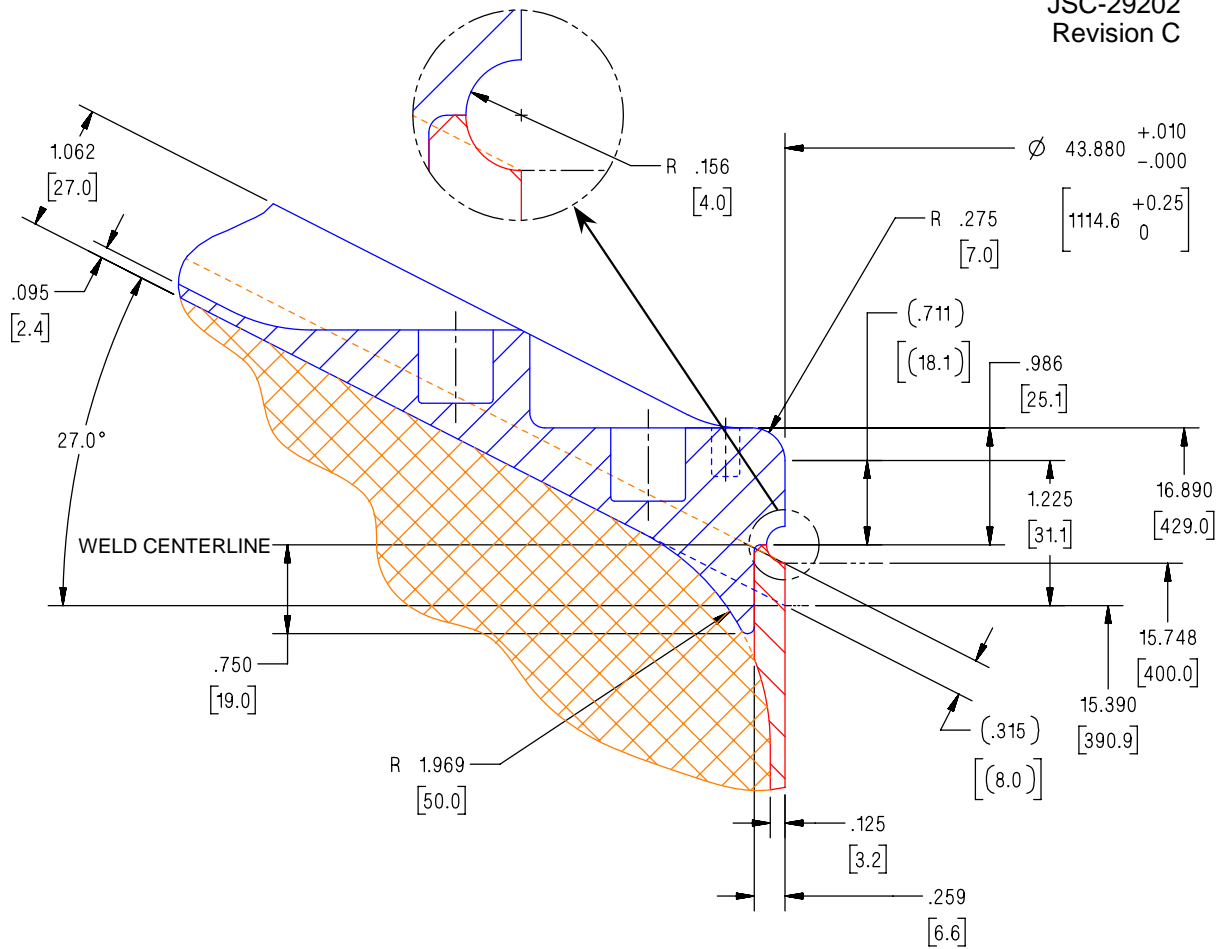


Figure 2.2.1-5 Inner Joint Detail

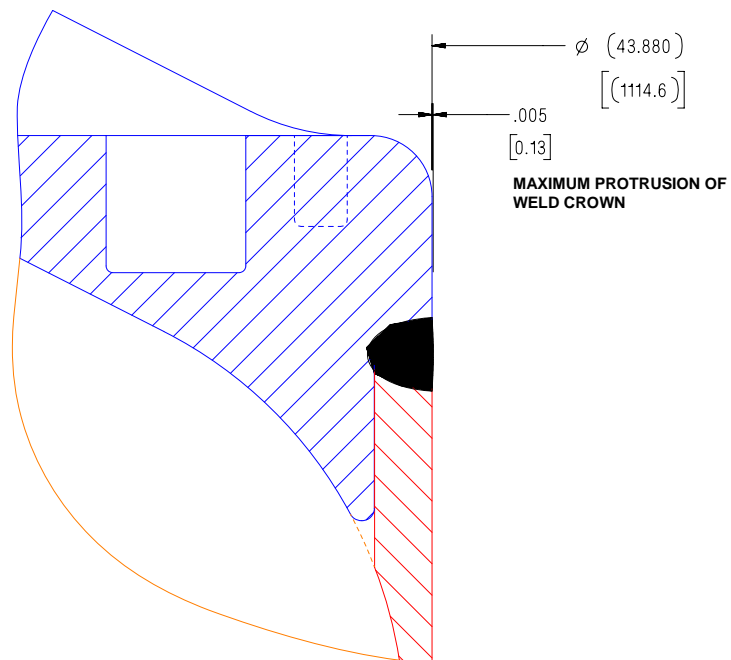


Figure 2.2.1-6 Closeout Weld

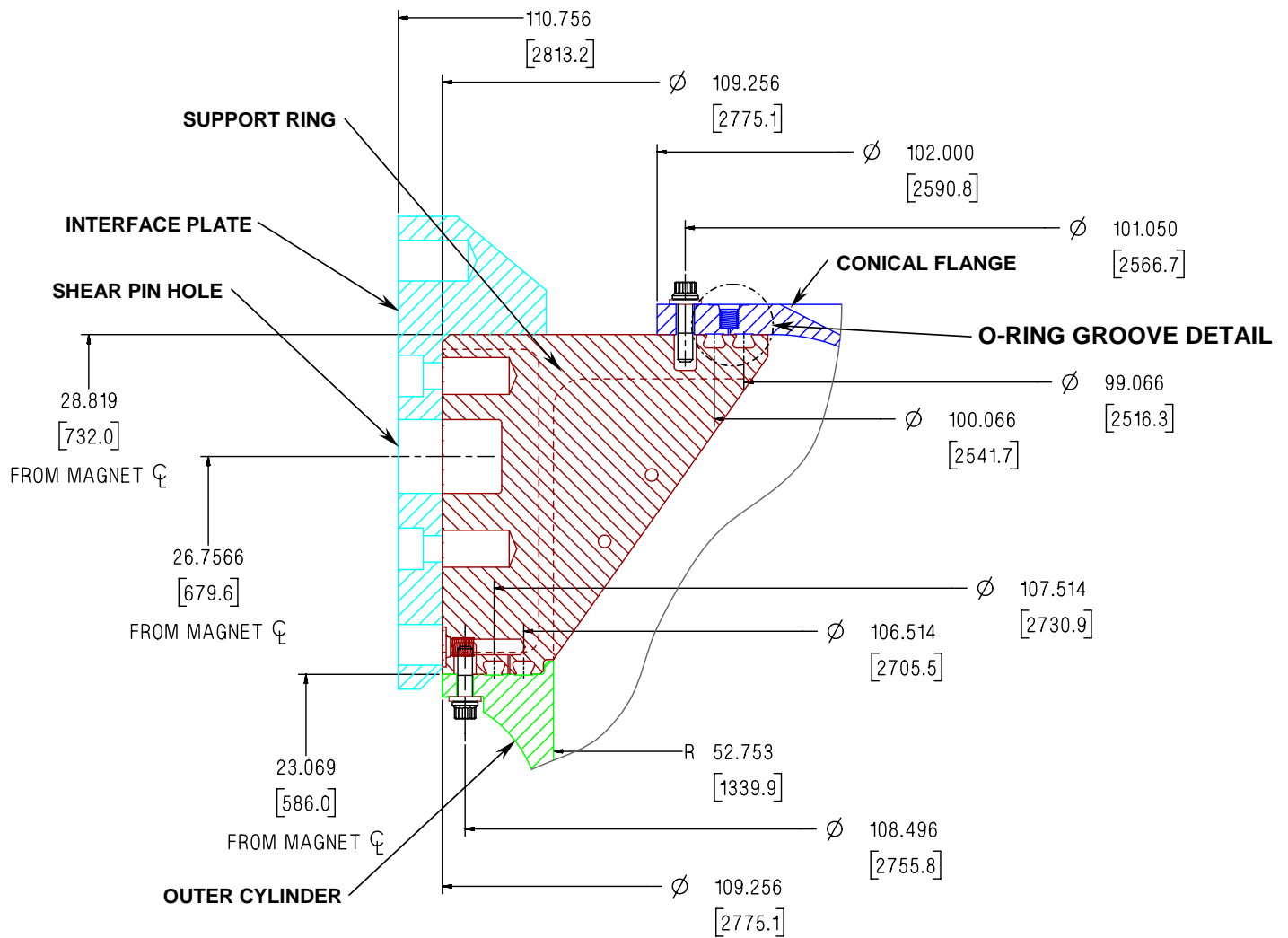


Figure 2.2.1-7 Outer Joint Detail

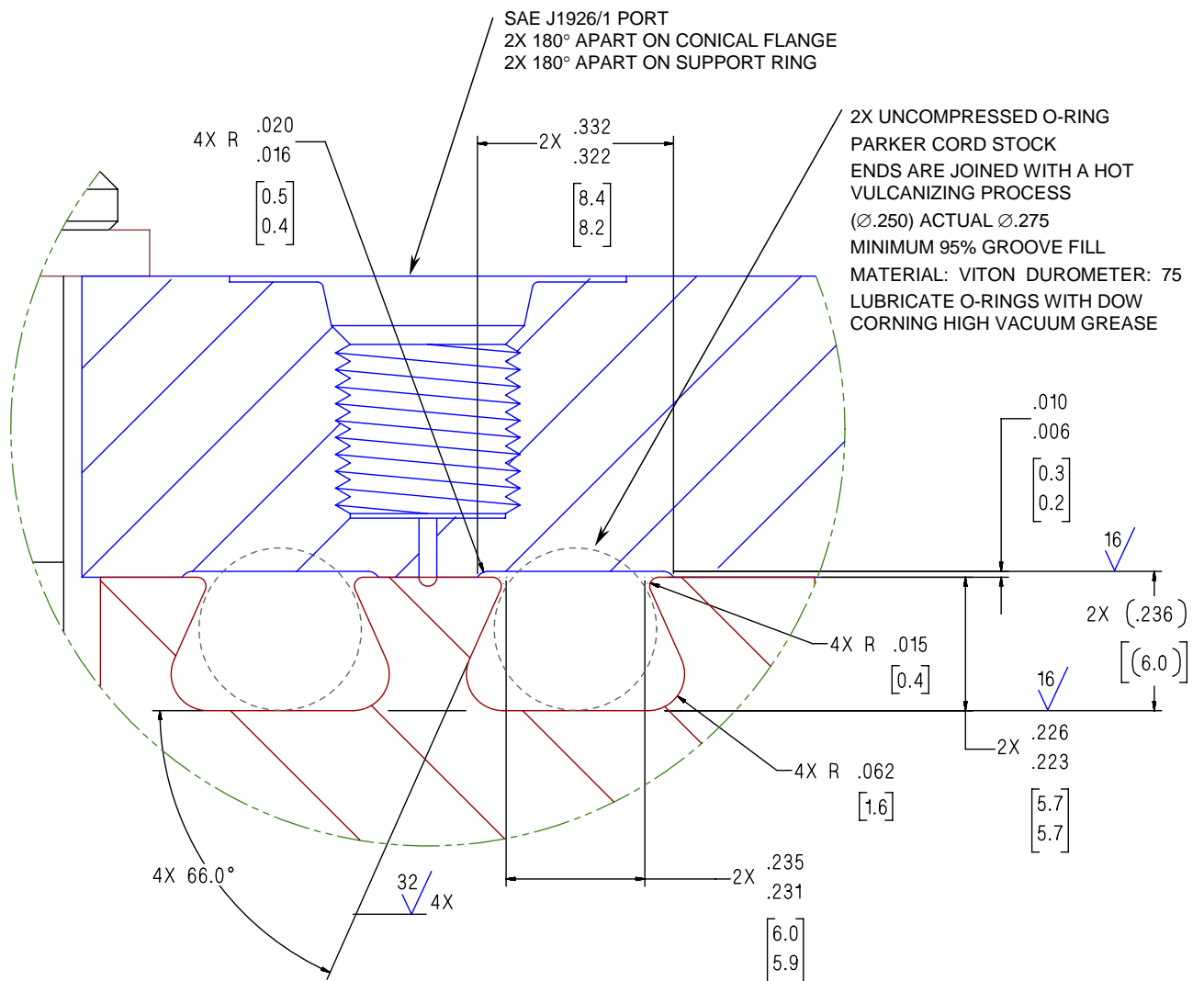


Figure 2.2.1-8 O-Ring Groove Detail

2.2.2 Temporary Seal

A temporary seal will be used prior to the final closeout weld in order to test the Vacuum Case and Cold Mass. This seal is shown in Figure 2.2.2-1 and will be at both ends of the VC. The temporary seal will be provided by ETH/SCL.

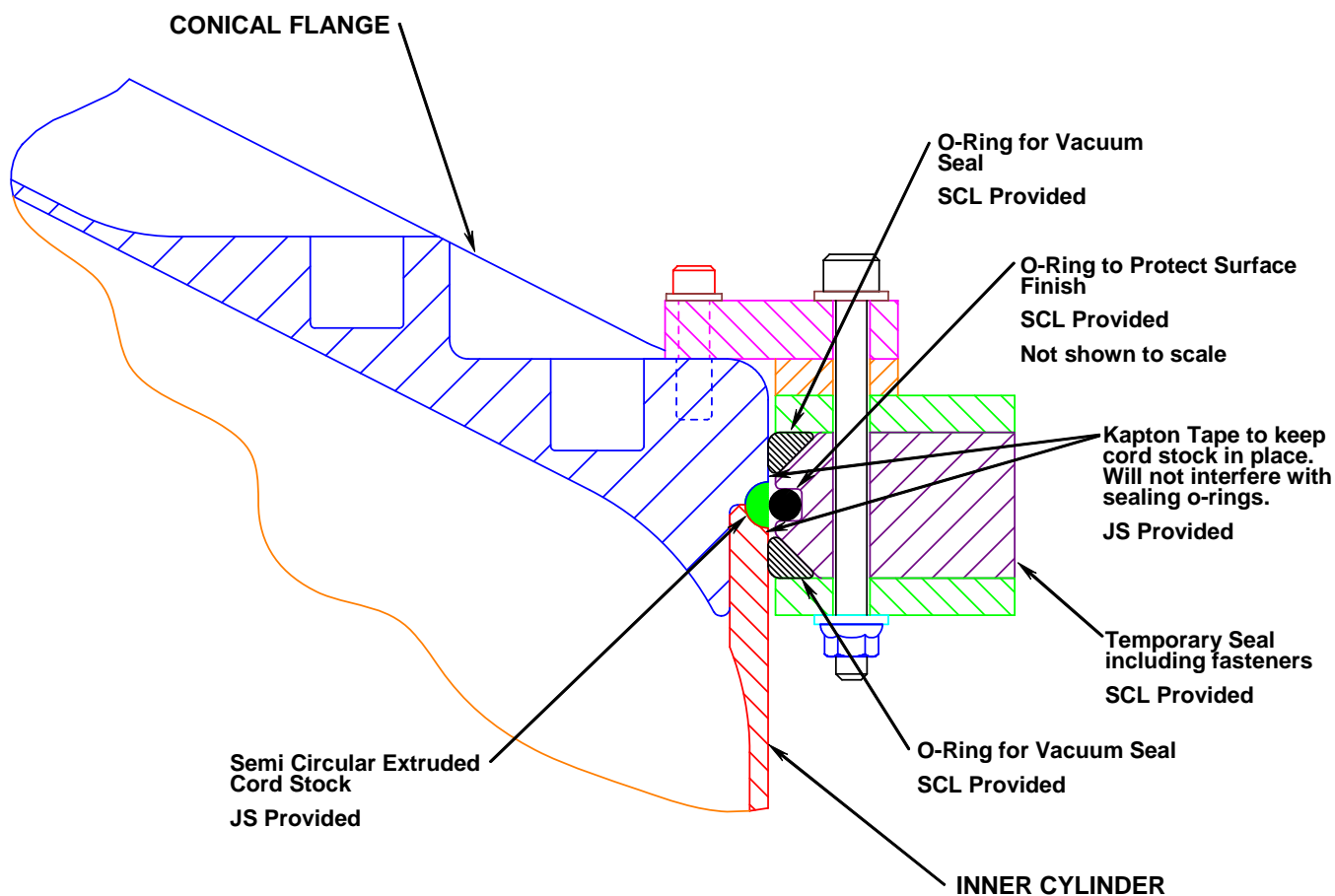


Figure 2.2.2-1 Temporary Seal

2.2.3 Magnet Support System

The Cryomagnet, Super Fluid Helium Tank, and Cryosystem are all supported to the Vacuum Case through the Magnet Support System. The Magnet Support System is comprised of 16 non-linear composite straps that connect to the Vacuum Case as shown in Figures 2.2.3-1 through 2.2.3-7. The Closeout Cap (provided by ETH/SCL) for these straps is shown in Figure 2.1.3-8.

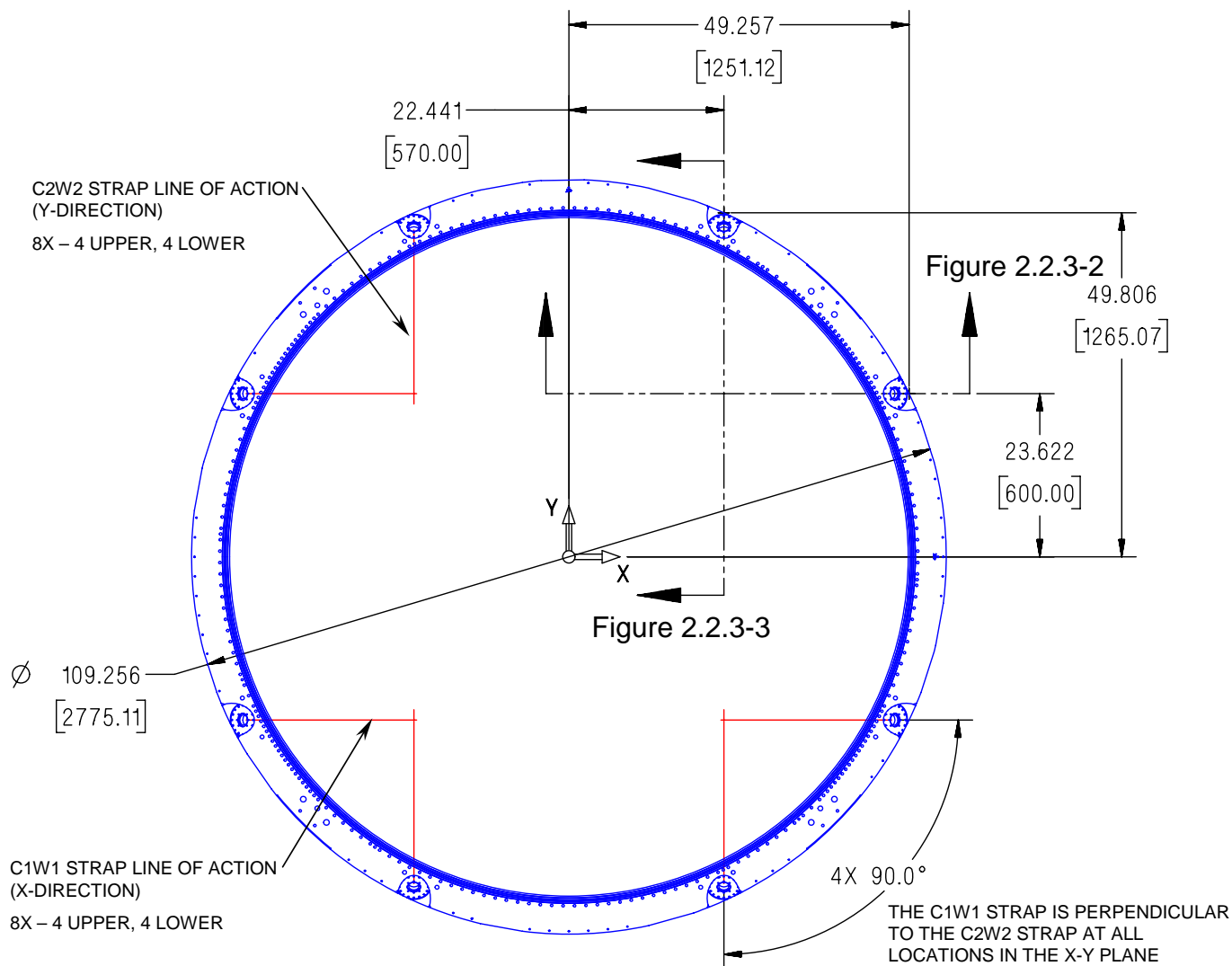


Figure 2.2.3-1 Support Strap Locations

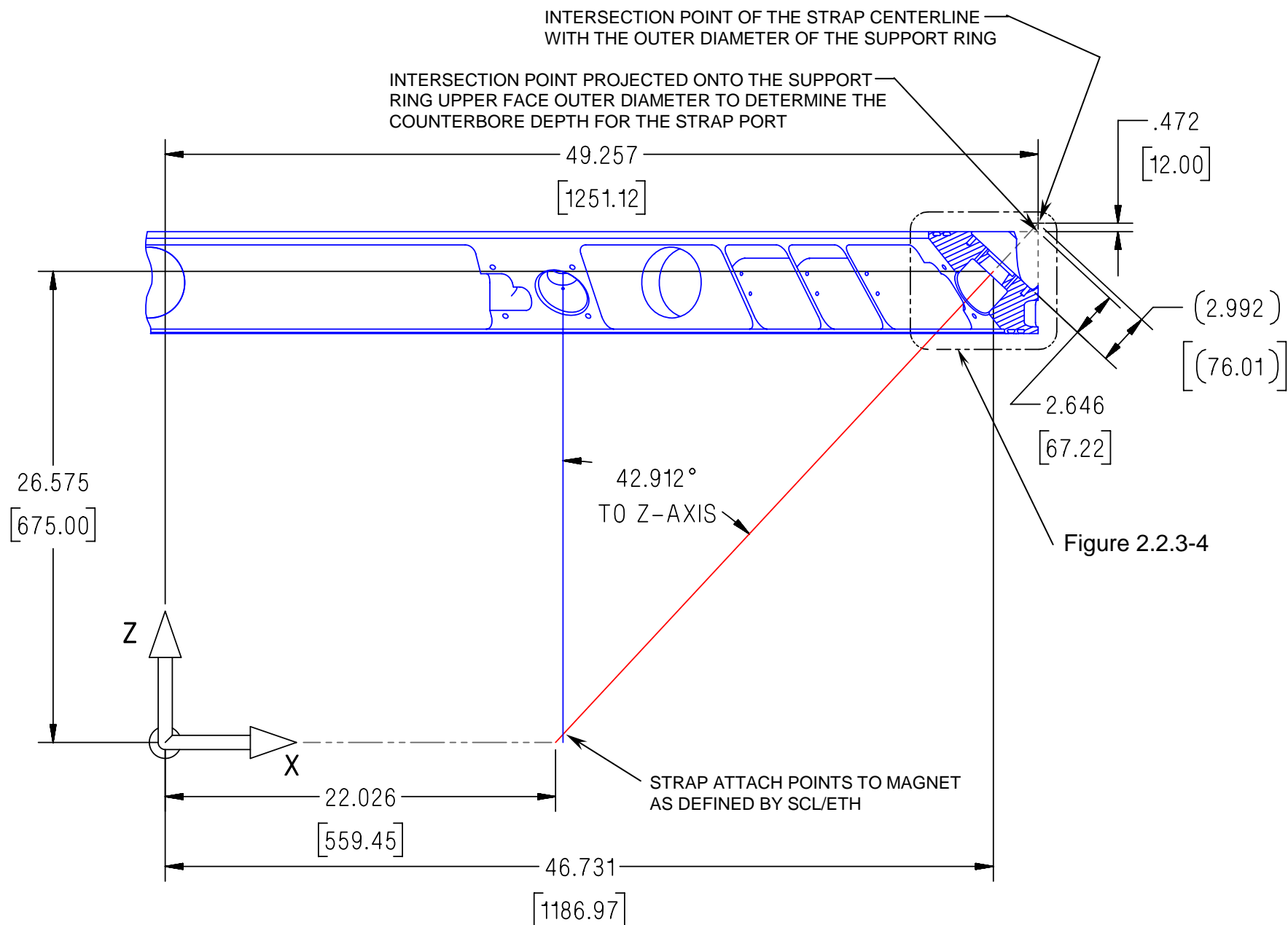


Figure 2.2.3-2 Section Thru Strap Port C1W1 (X-direction)

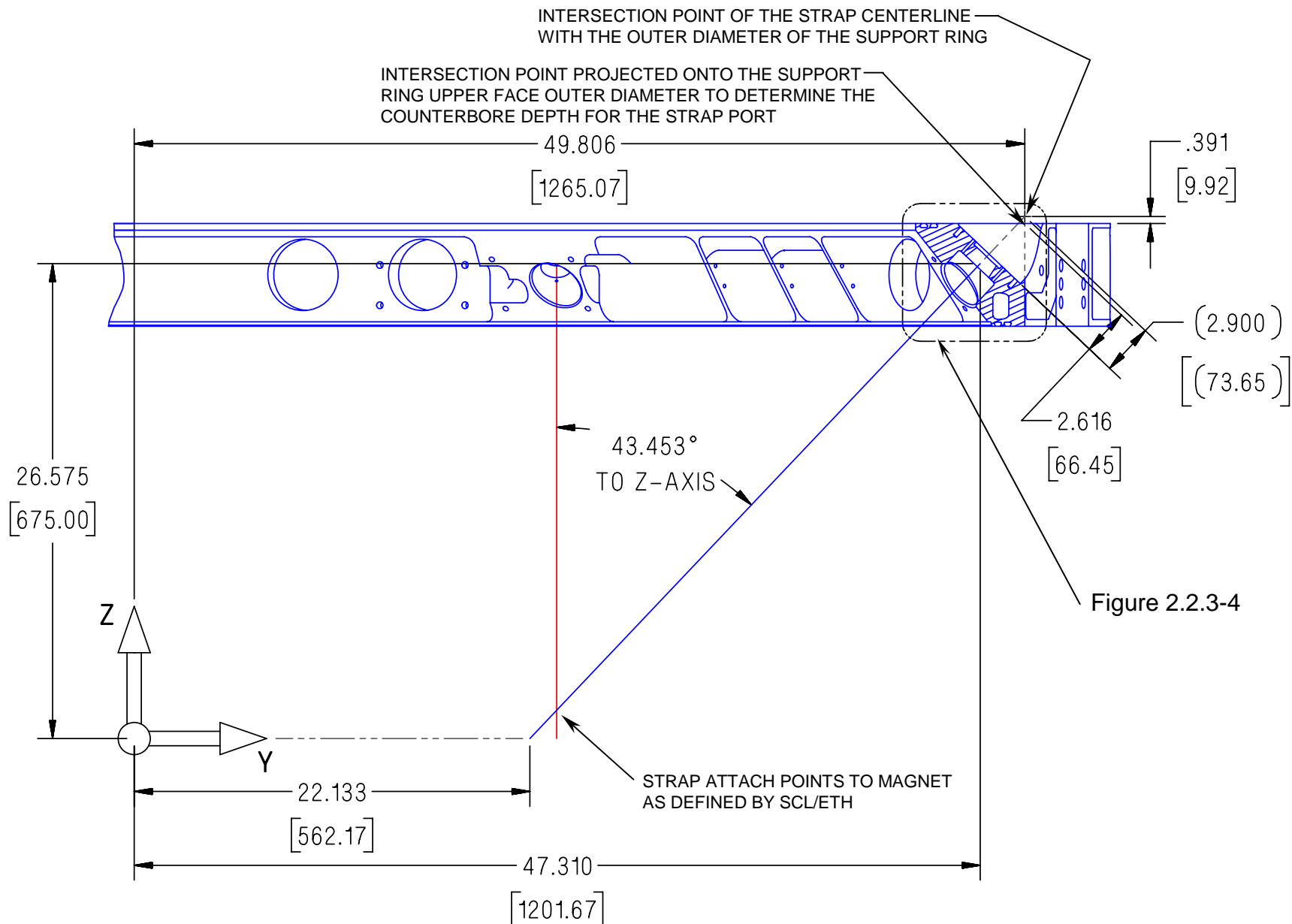


Figure 2.2.3-3 Section Thru Strap Port C2W2 (Y-direction)

NOTE: Strap angle shown
is generic. Specific feed-
thru angles are defined in
Figures 2.2.3-2 and 2.2.3-3.

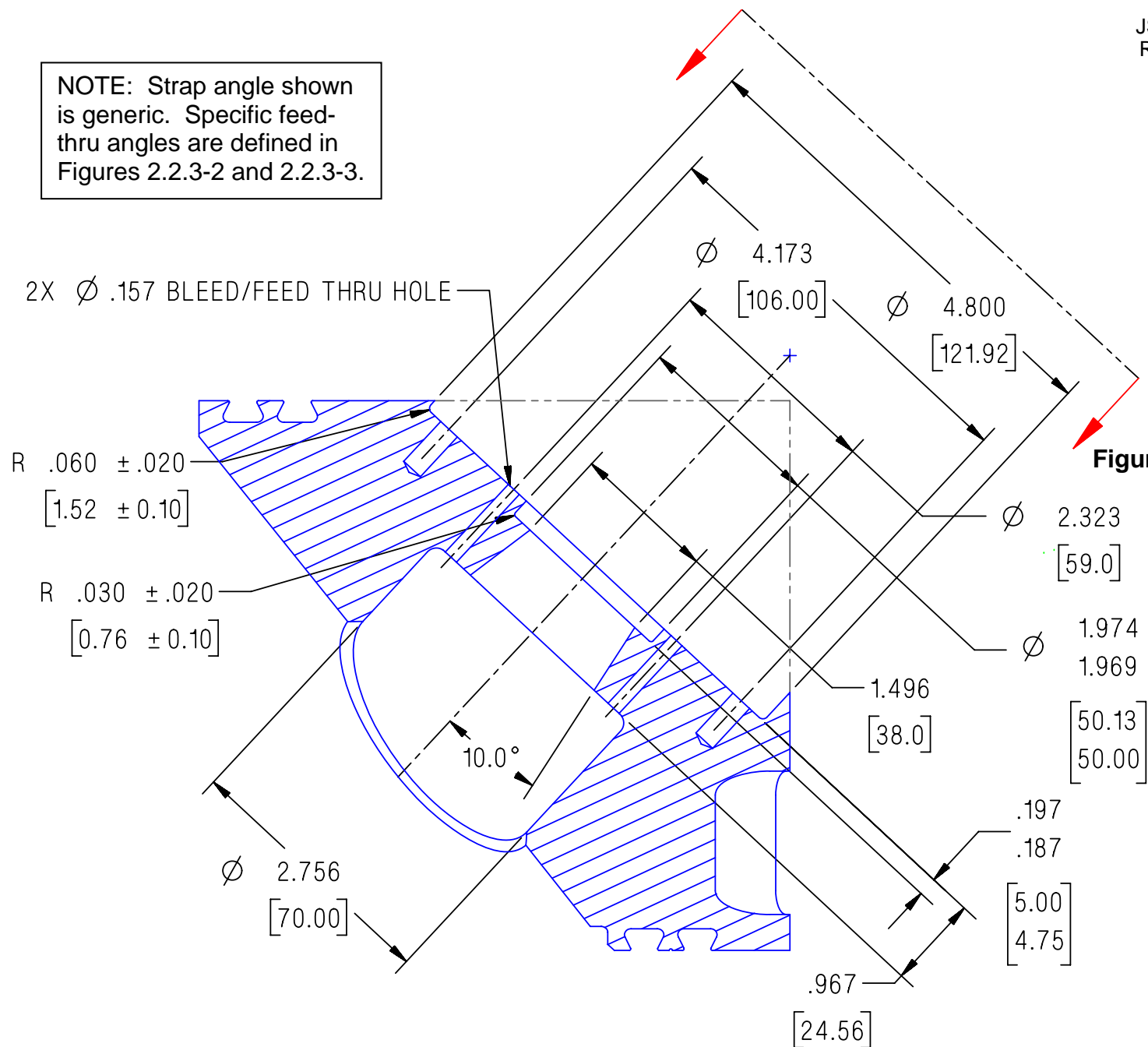


Figure 2.2.3-5

Figure 2.2.3-4 Strap Feed-Thru Detail

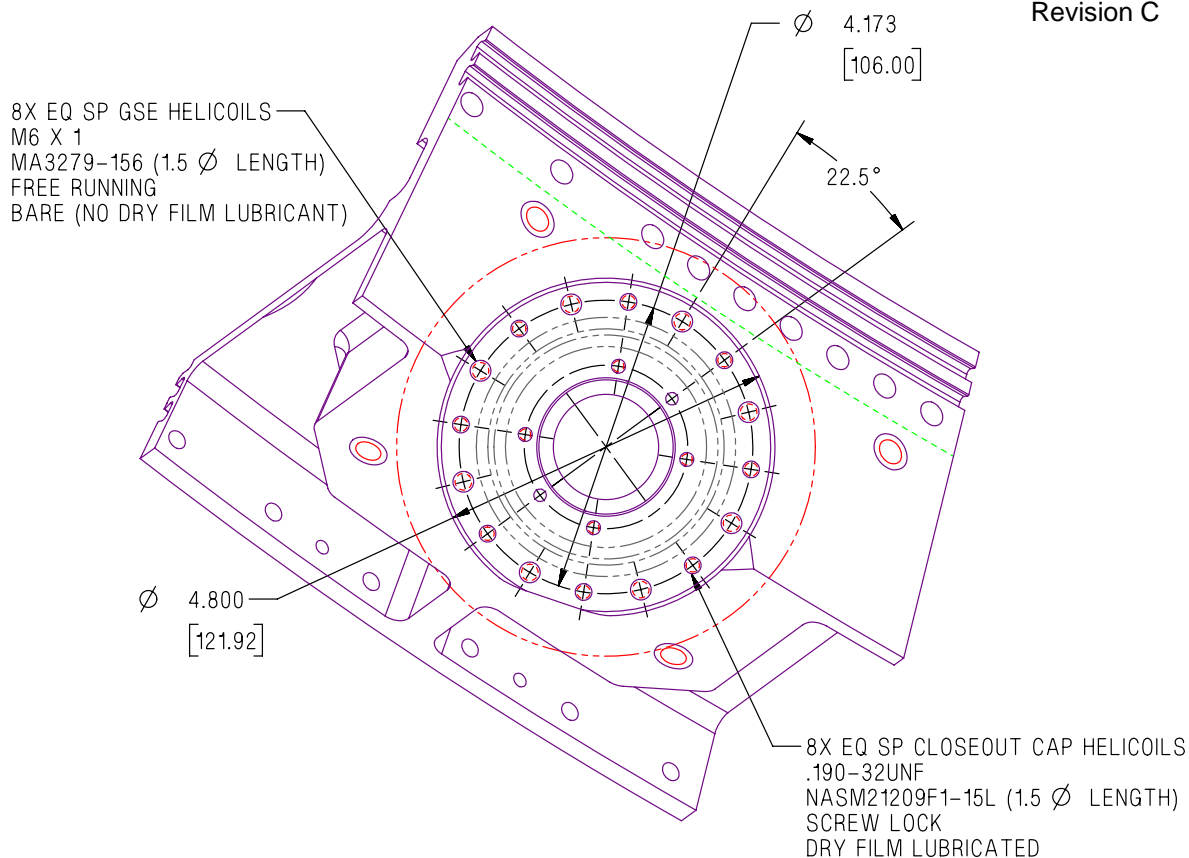


Figure 2.2.3-5 Strap Feed-Thru Face View

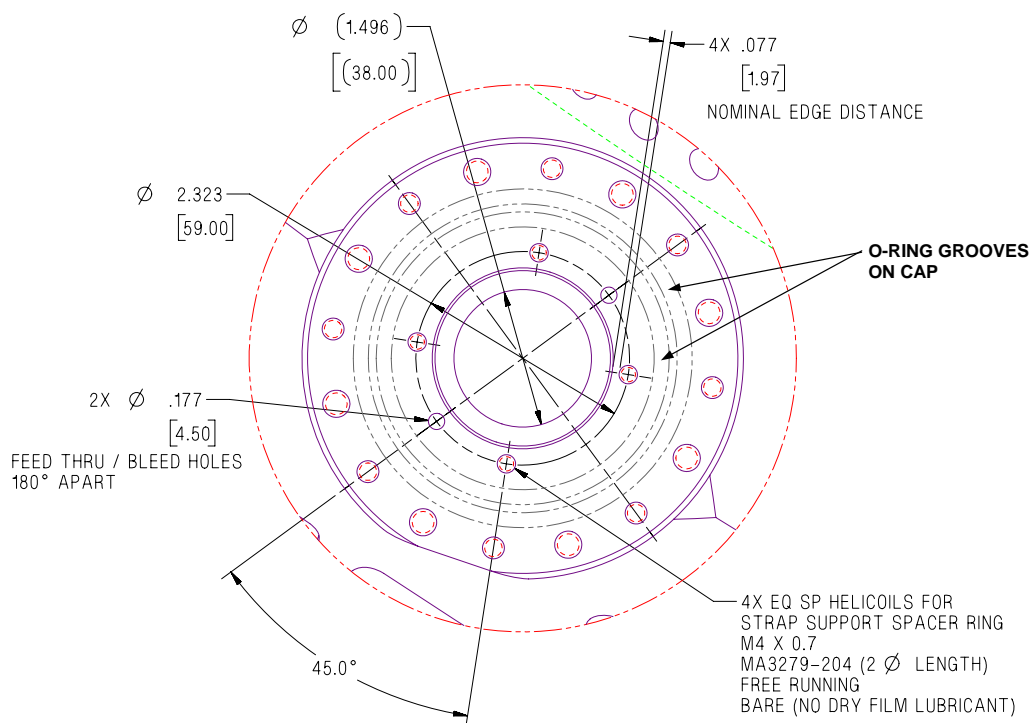


Figure 2.2.3-6 Strap Feed-Thru Detail View

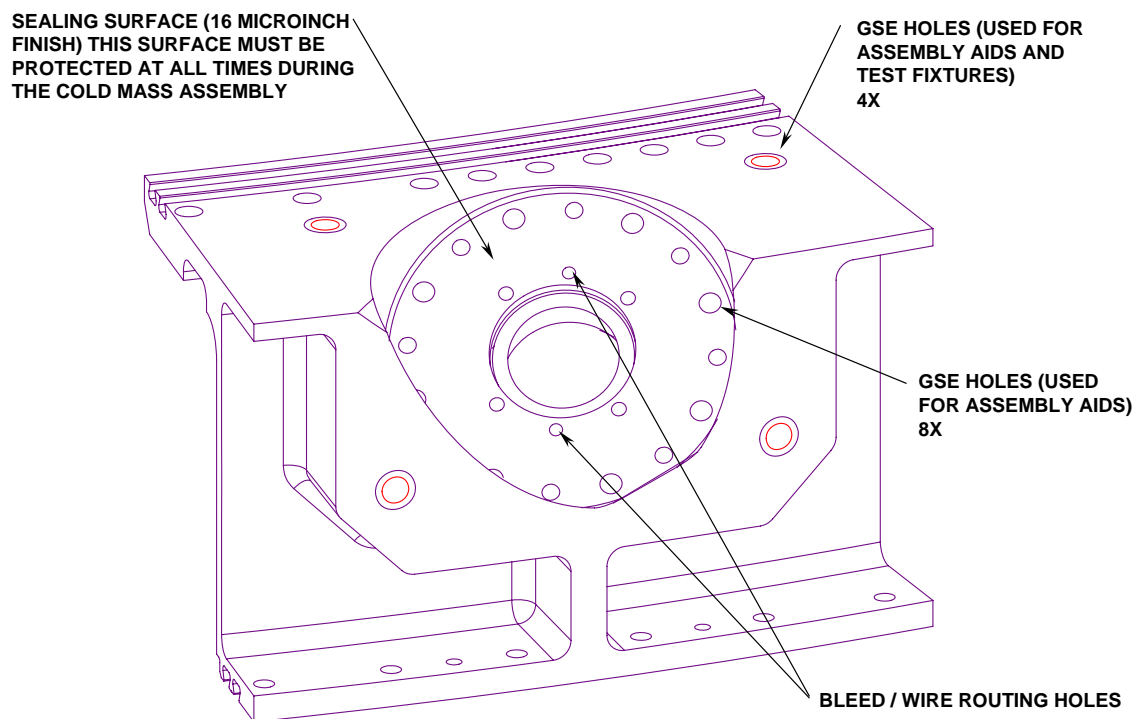


Figure 2.2.3-7 ISO View of Strap Port

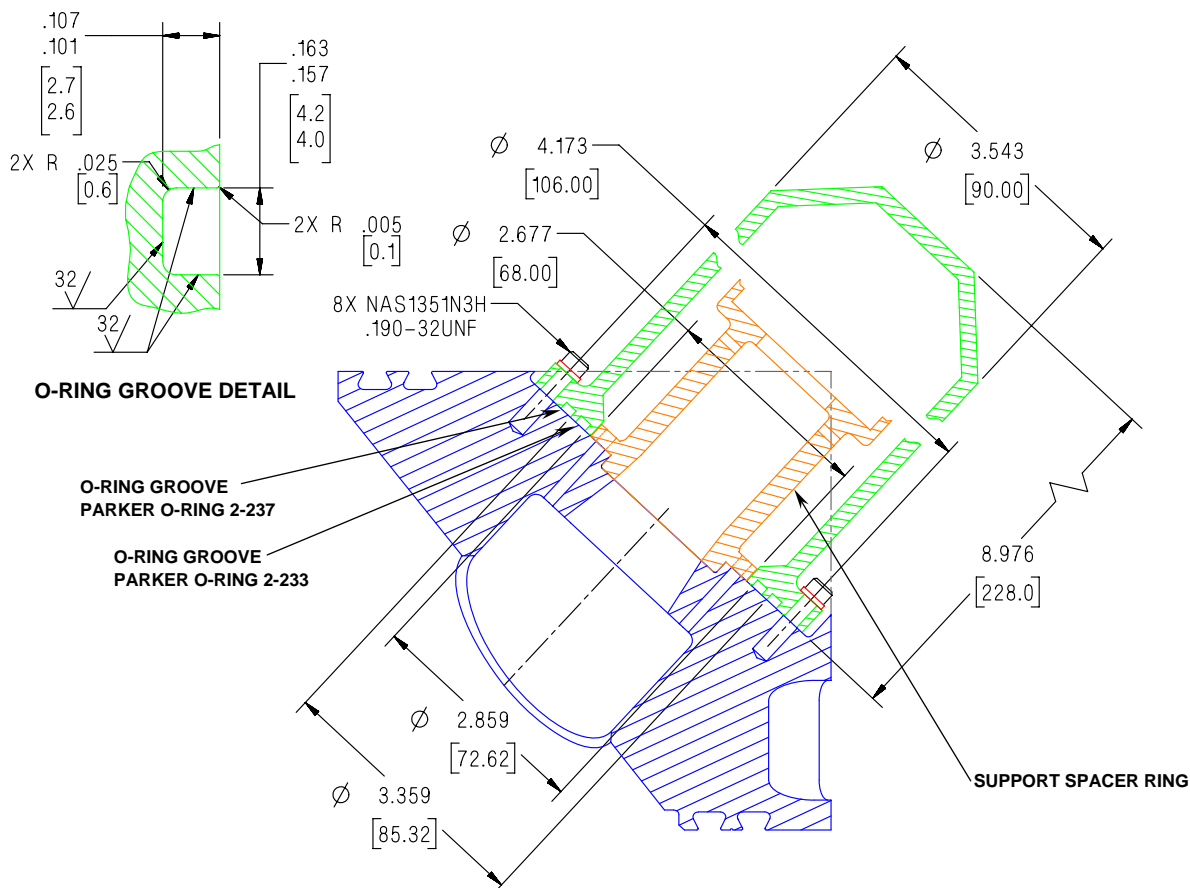


Figure 2.2.3-8 Strap Closeout Cap (Provided by ETH/SCL)

2.2.4 Feed-Thru Port Locations

There are numerous plumbing lines and electrical cables that need to penetrate the Vacuum Case. All of the ports will be in the upper and lower support rings of the Vacuum Case. The orientations are shown in Figures 2.2.4-1, 2.2.4-2 and 2.2.4-3. Temporary port closeout covers (flat plates) will be provided by ESCG/NASA in order to perform vacuum leak checks prior to the installation of the final port closeout covers and caps. All Plumbing and Electrical flight closeout covers and caps will be provided by ETH/SCL. The temporary port closeout covers provided by ESCG/NASA will be available for flight closeout on ports that do not require any feedthru cables or tubes.

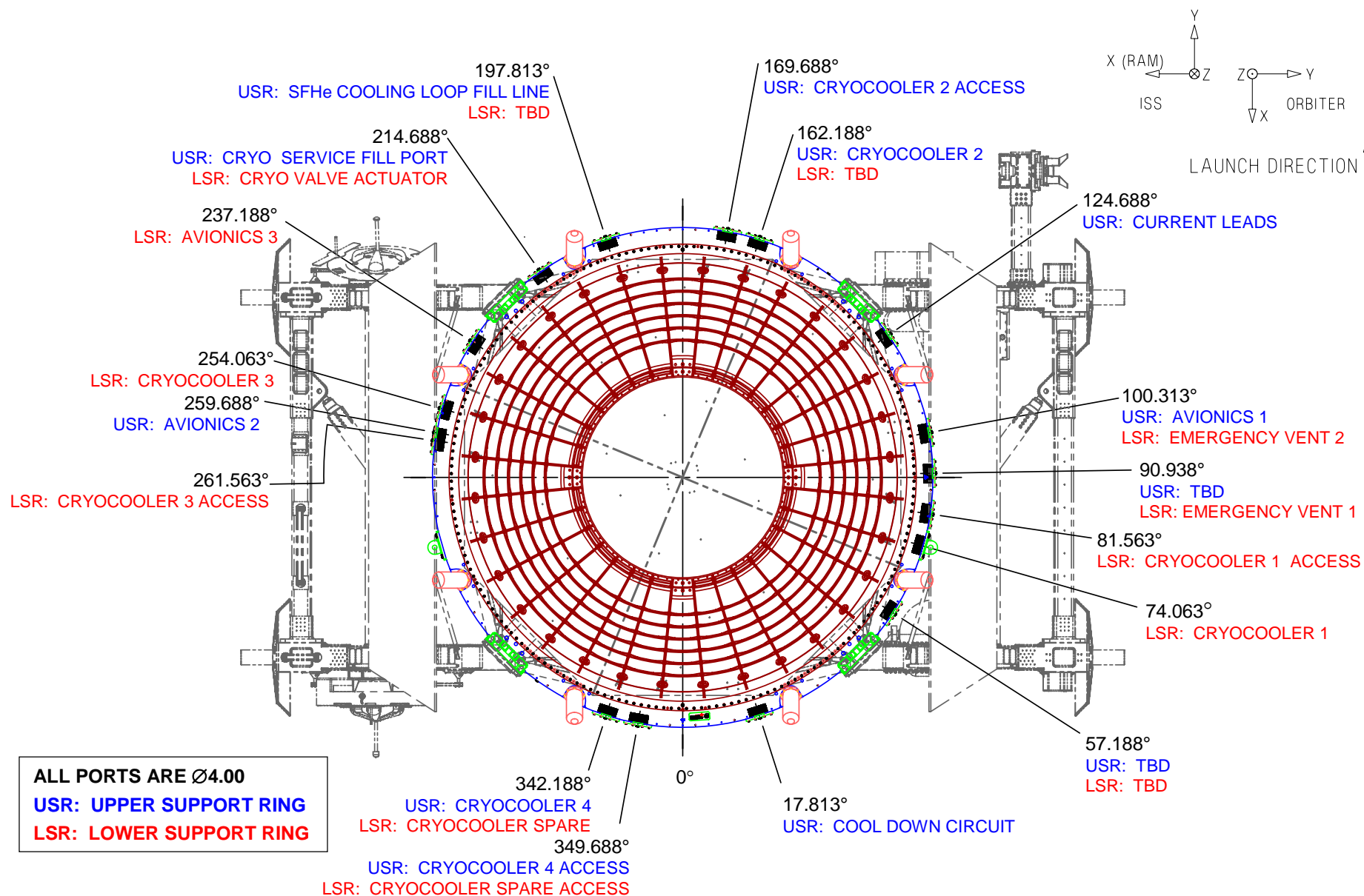


Figure 2.2.4-1 Plumbing and Electrical Port Locations

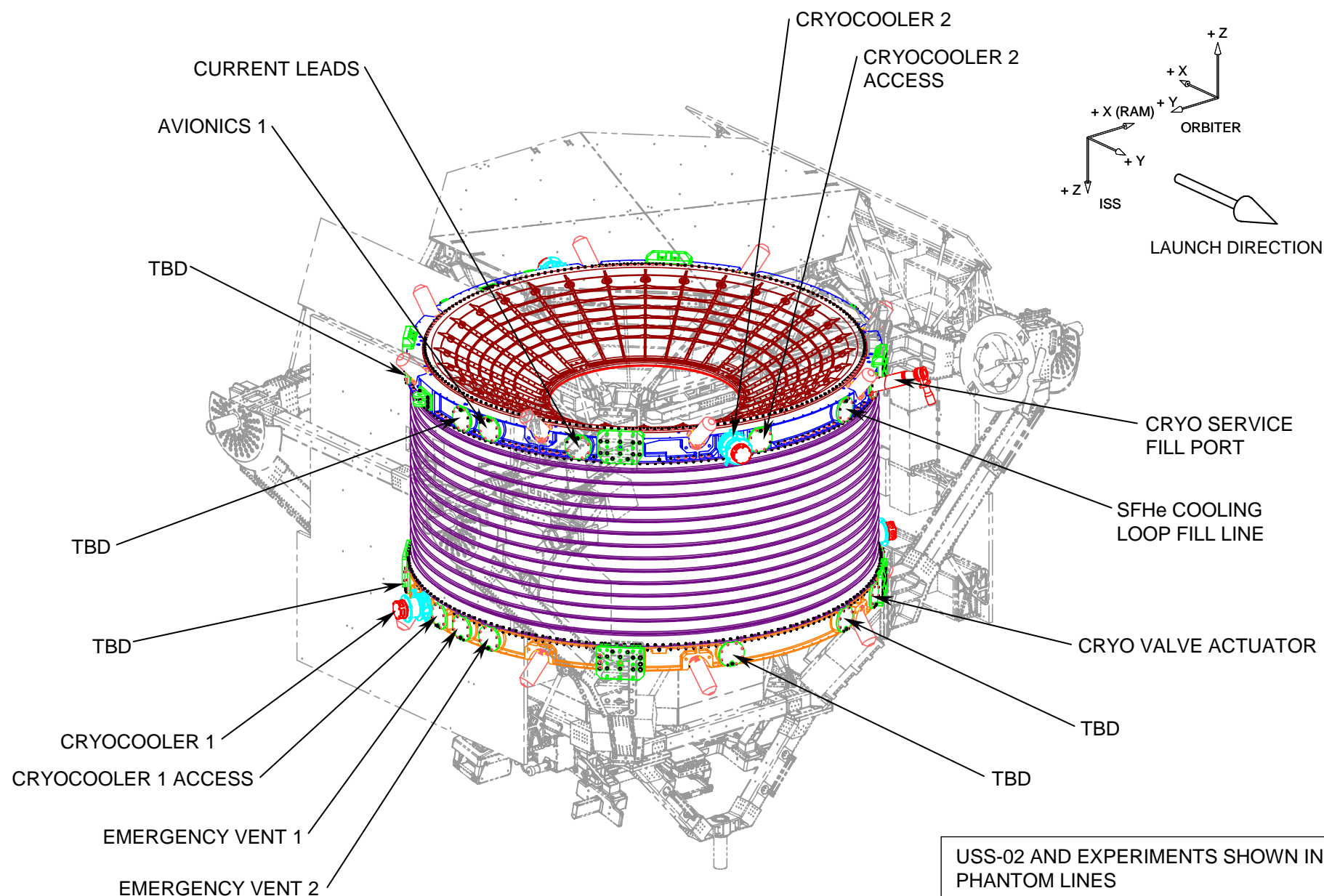
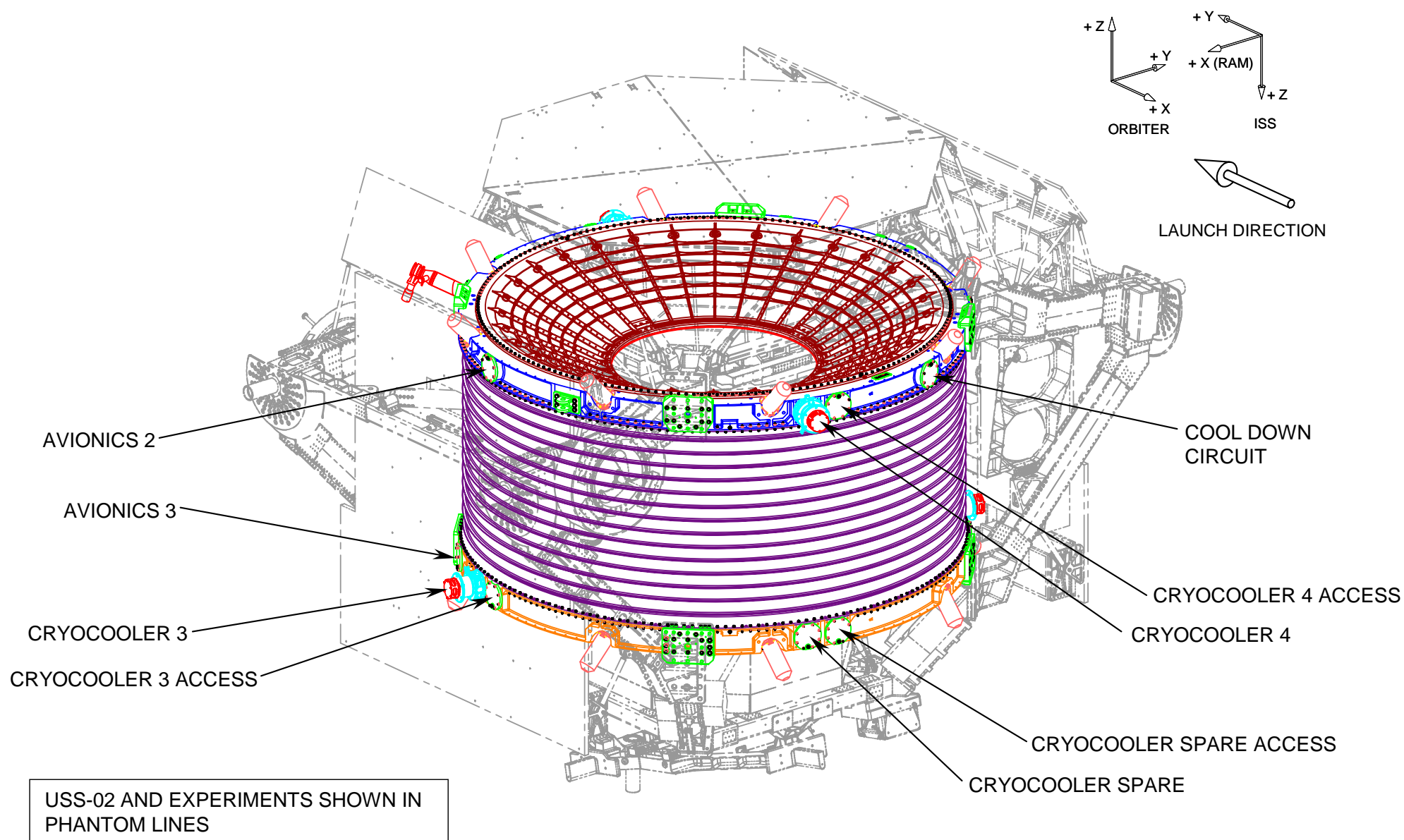


Figure 2.2.4-2 Port Locations – Front ISO View



2.2.5 Plumbing and Electrical Feed-Thru Ports

The plumbing and electrical feed-thru port is shown in Figure 2.2.5-1. The mating surface of the hardware that will attach to this port is shown in Figure 2.2.5-2. All mating hardware will incorporate a test port between the o-ring grooves so that each o-ring can be tested individually for vacuum integrity. ESCG/NASA will provide temporary closeout plates for the plumbing/electrical ports. The final flight closeout ports or caps will be provided by ETH/MIT/SCL/GSFC. The temporary port closeout covers provided by ESCG/NASA will be available for flight closeout on ports that do not require any feedthru cables or tubes.

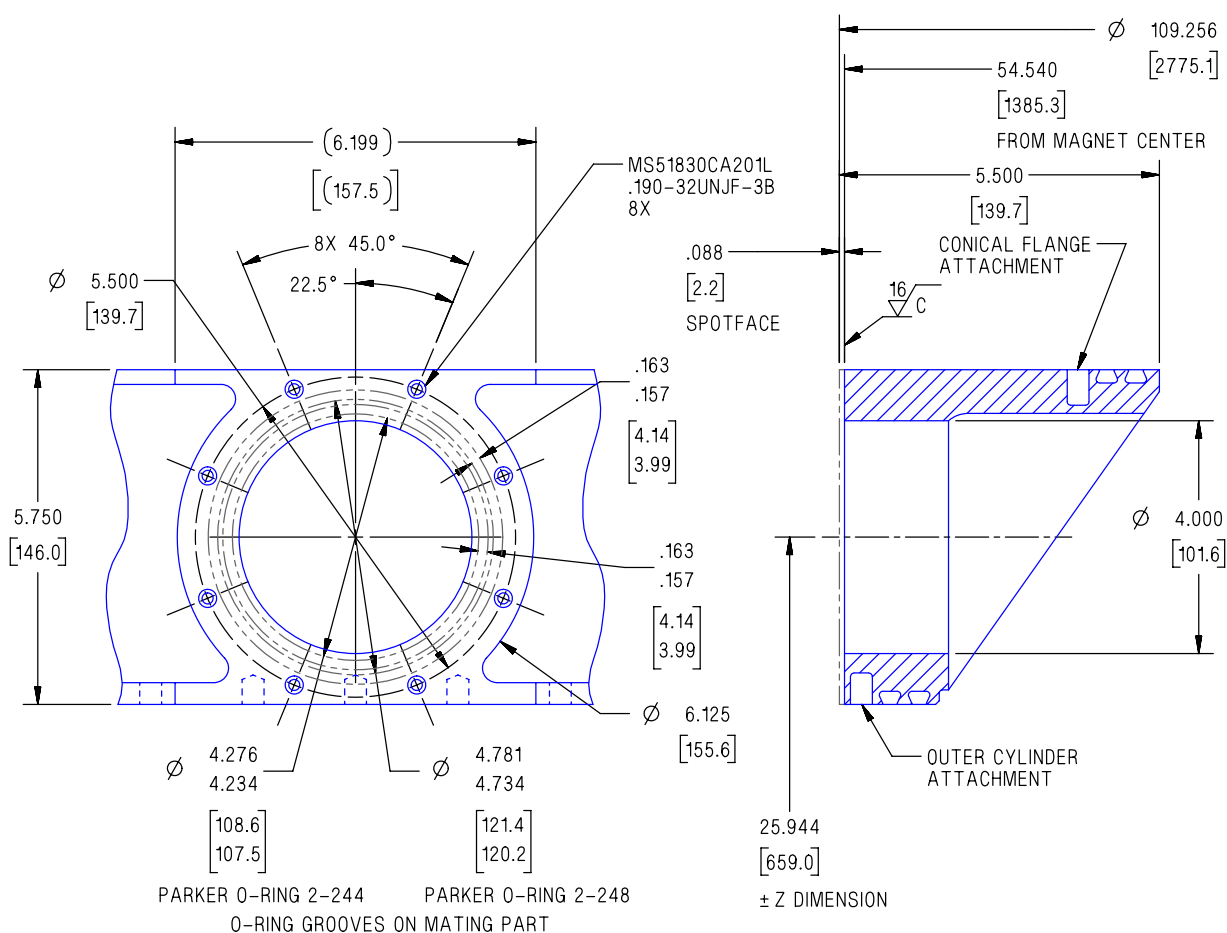


Figure 2.2.5-1 Plumbing/Electrical Port

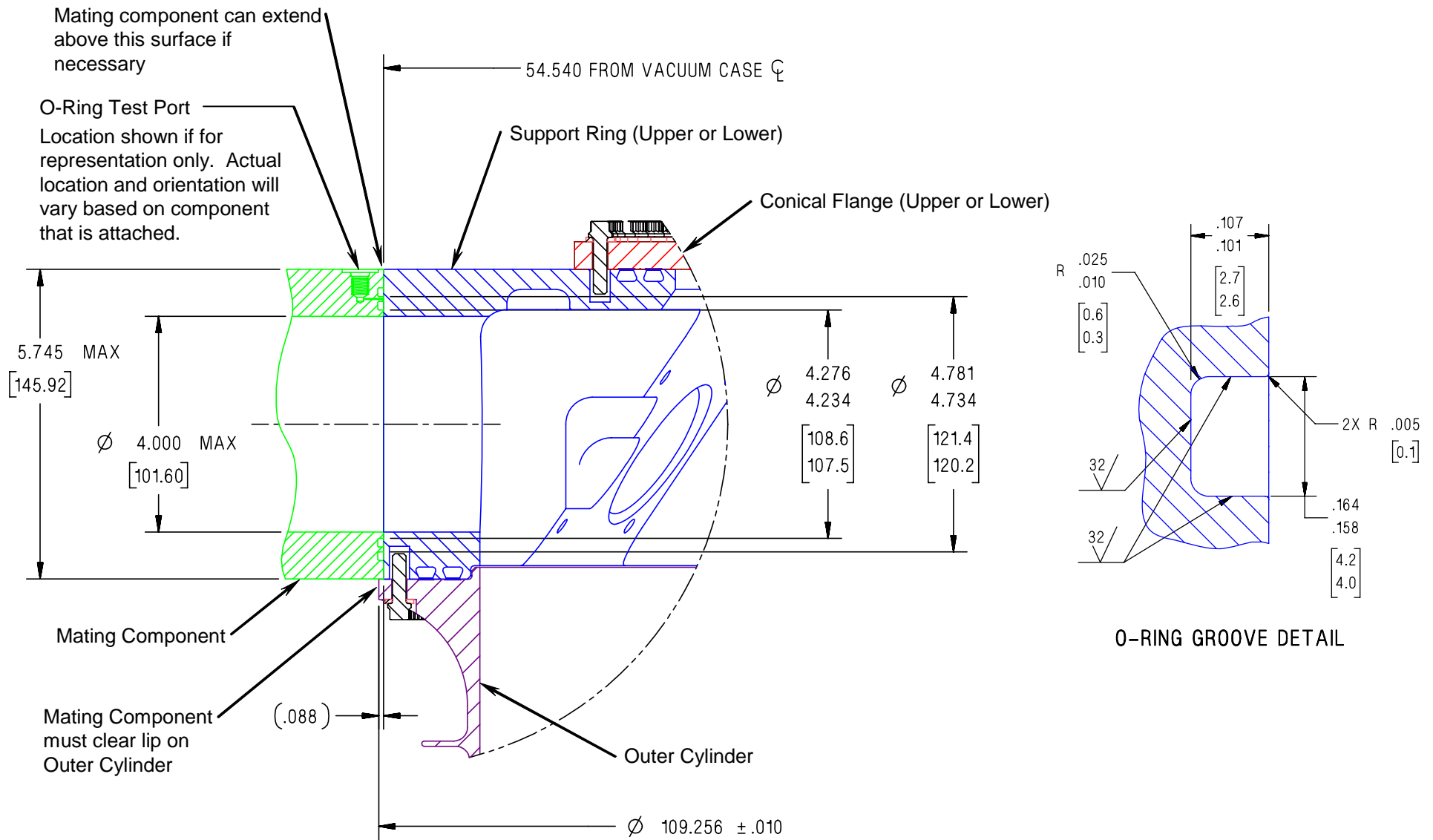
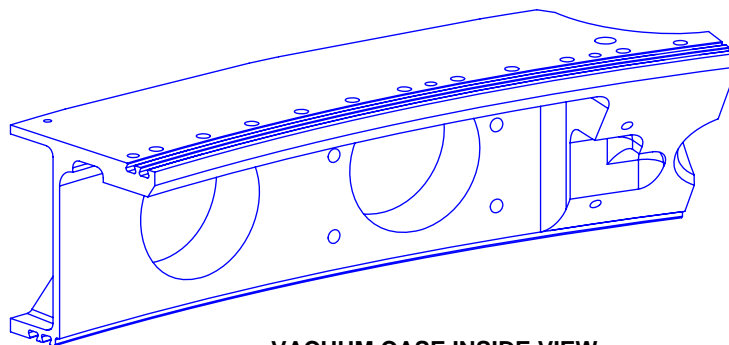


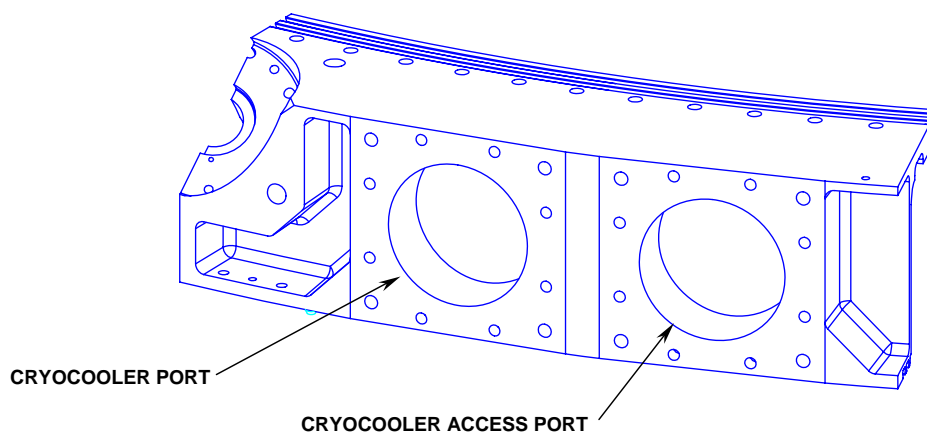
Figure 2.2.5-2 Mating Component for Feed Thru Ports

2.2.6 Cryocooler Interfaces and Ports

Four cryocoolers will be mounted to the Vacuum Case Upper and Lower Rings. The current mounting location (Figures 2.2.4-1, 2, and 3) and ports are shown in Figure 2.2.6-2. Figure 2.2.6-1 shows a front and back ISO view the port. The cryocooler mating surface to the Vacuum Case shall be per Figure 2.2.5-2. The cryocooler heat dissipation is taken to an external radiator by two Loop Heat Pipe devices. The mating surface of the cryocooler to the Loop Heat Pipes shall be per Figure 2.2.6-3. The cryocooler access port is identical to the cryocooler port and allows access to the cold head once the cryocooler is installed. The ports are essentially the same as the 4 inch diameter ports shown in Figure 2.2.5-1 and 2 with the addition of the 4 mounting holes at the corners on the outside and the inside. The VC design includes enough ports to actually mount five cryocoolers, but the fifth location will only be used in a contingency event. ESCG/NASA will provide temporary closeout plates for the cryocooler ports. The final flight closeout ports or caps will be provided by ETH/MIT/SCL/GSFC. All cryocoolers and flight closeout caps will incorporate a test port between the o-ring grooves so that each o-ring can be tested individually for vacuum integrity. The temporary port closeout covers provided by ESCG/NASA will be available for flight closeout on ports that do not require any feedthru cables or tubes.



VACUUM CASE INSIDE VIEW



VACUUM CASE OUTSIDE VIEW

Figure 2.2.6-1 Cryocooler Port ISO Views

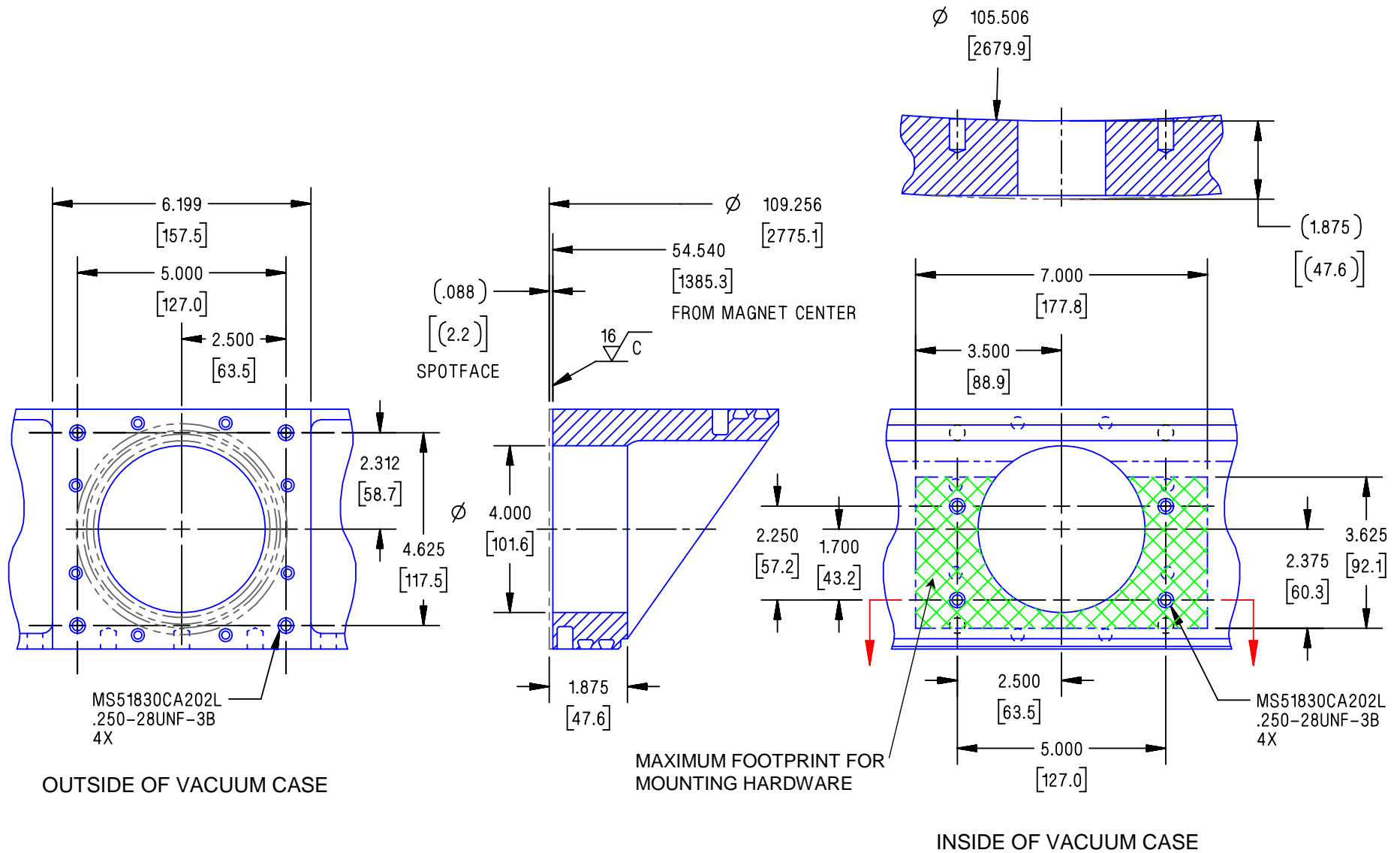
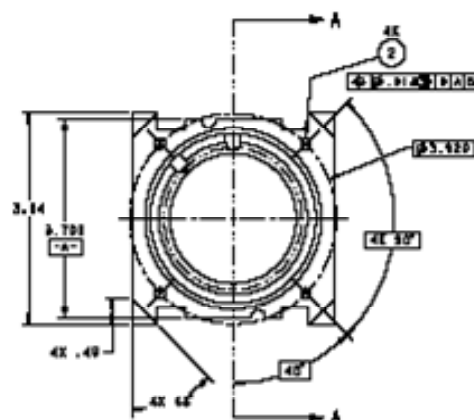
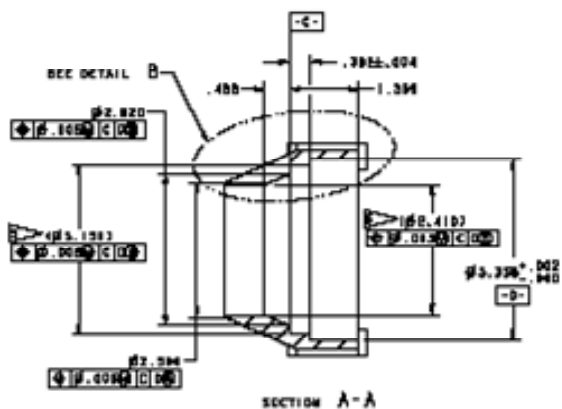


Figure 2.2.6-2 Cryocooler Interfaces and Ports

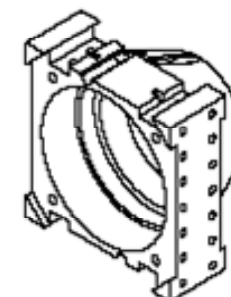
NOTES: UNLESS OTHERWISE SPECIFIED

1. INSTALL THREADED INSERTS IN ACCORDANCE WITH MS33537 AND REMOVE DRIVIN TAPERS.
2. INSTALL THREADED INSERTS IN ACCORDANCE WITH SAE-MS1987 AND REMOVE DRIVIN TAPERS.
3. ORIGINAL SOURCE OF SUPPLY:
EMART FASTENING TECHNOLOGIES
INDUSTRIAL DIVISION
MELTON, CT 06464-0171
4. SAE PART 148 MIL-STD-2079-1 METHOD 19,
AND TAB WITH PART NUMBER "88145".

▶ MACHINE DIMENSION 4.003 - .400 TO FIT YGNDOR PART (887, CRYSTOCOLCE ITEM 173 AT NEXT HIGHER ASSEMBLY.



SPY IN 88				
STP	NAME	PHONE STP IN	DATE	APPRO
4		XXXXXXXXXX IN STP 1 STP 2	DATE	



100 VIEW
FOR REFERENCE ONLY
SCALE 1/1

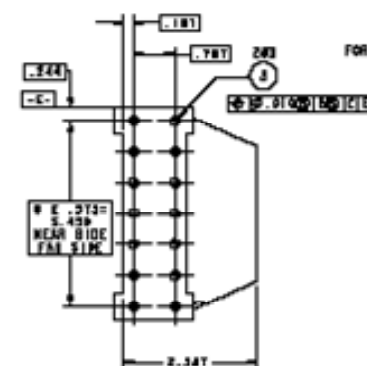


Figure 2.2.6-3 Cryocooler Interfaces

2.2.7 Cryo Service Port

A cryo service port will be mounted to the Vacuum Case Upper Ring. The current mounting location (Figures 2.2.4-1, 2, and 3) and port are shown in Figure 2.2.7-1. Layouts of the cryo service port are shown in Figures 2.2.7-2 through 2.2.7-4. The cryo service mating surface to the Vacuum Case shall be per Figure 2.2.5-2. The cryo service port is used to service the cryogenic system on the ground. The ports are essentially the same as the 4 inch diameter ports shown in Figure 2.2.5-1 and 2 with the addition of the 4 mounting holes at the corners on the outside. ESCG/NASA will provide a temporary closeout plate for the cryo service port. The final flight closeout ports or caps will be provided by ETH/MIT/SCL. The cryo service port will incorporate a test port between the o-ring grooves so that each o-ring can be tested individually for vacuum integrity.

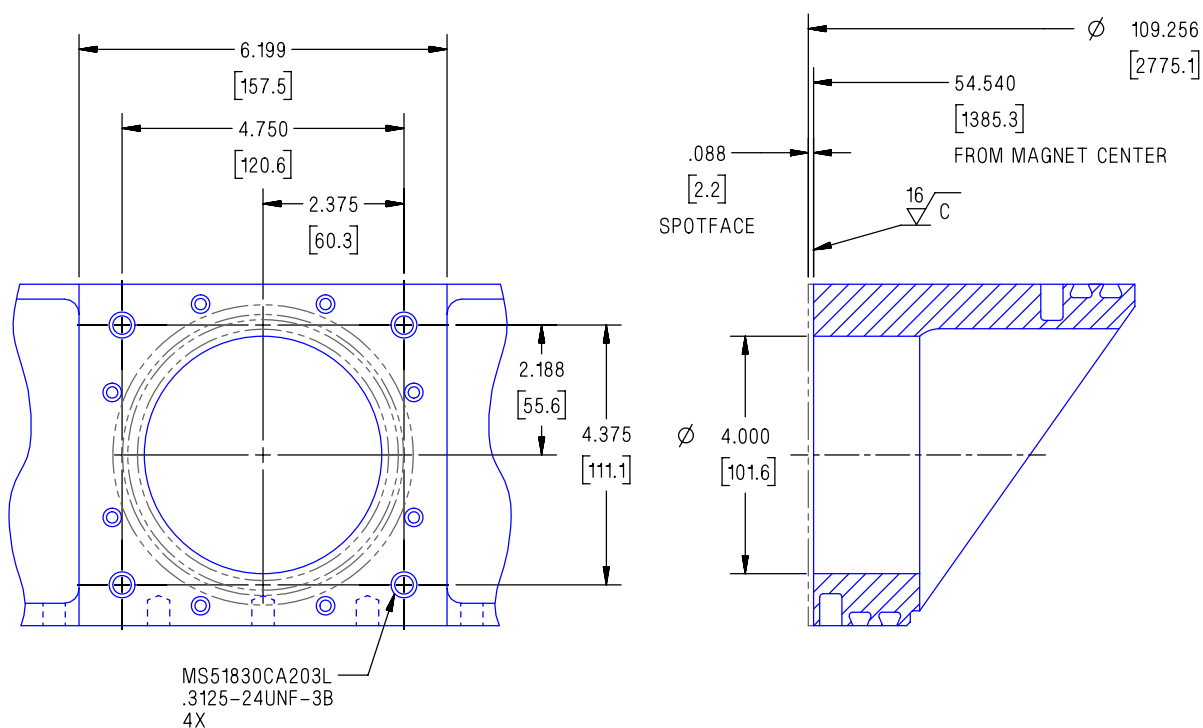


Figure 2.2.7-1 Cryo Service Port

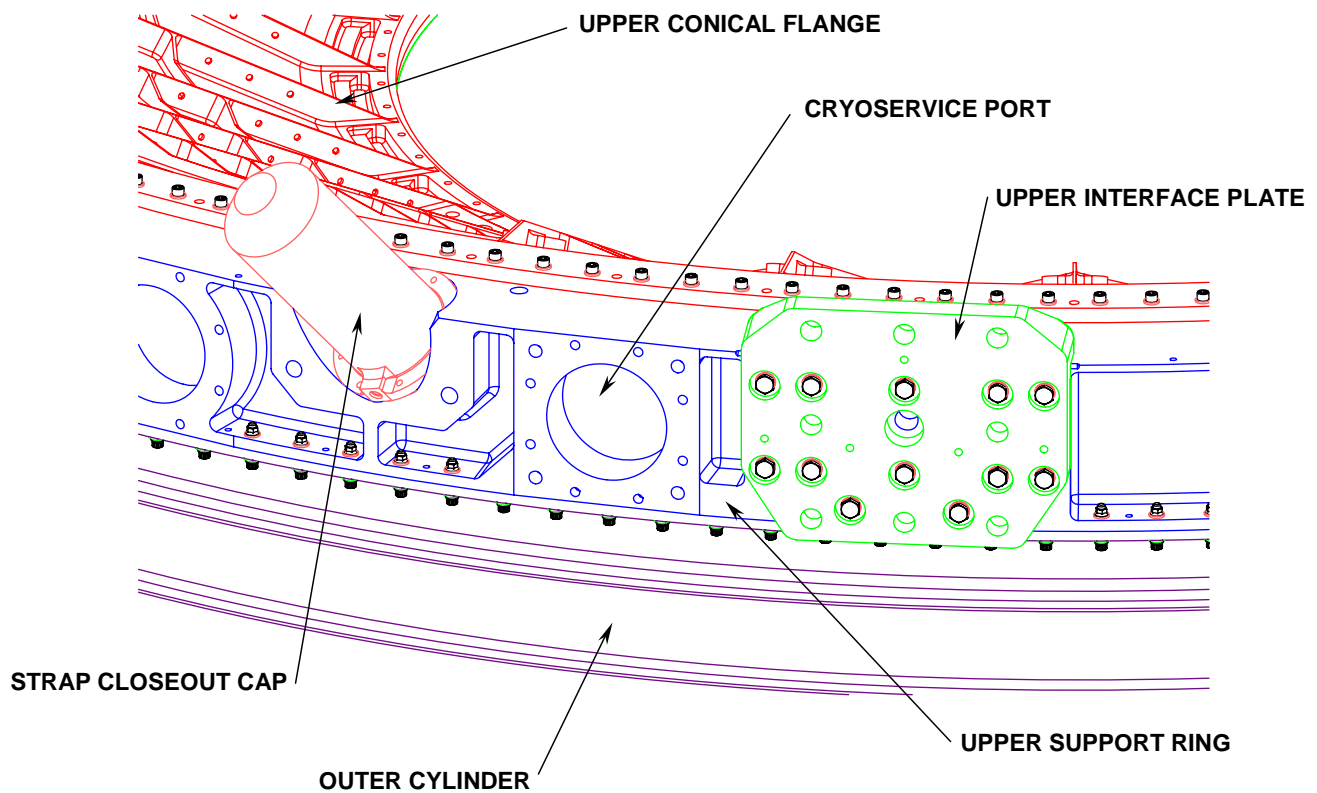


Figure 2.2.7-2 Cryo Service Port Layout – Front ISO View

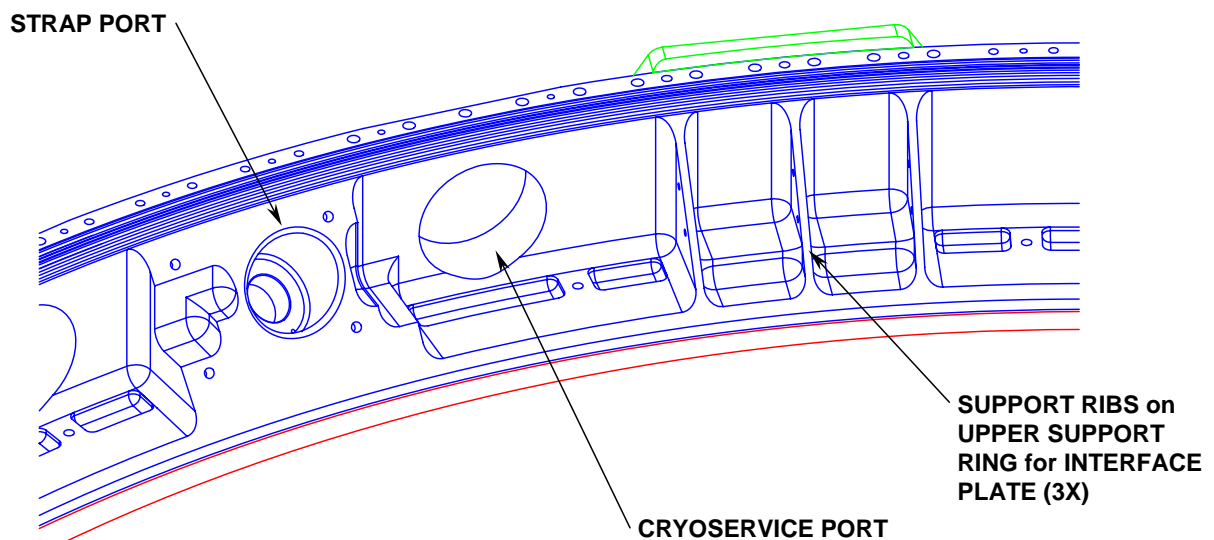


Figure 2.2.7-3 Cryo Service Port Layout – Back ISO View

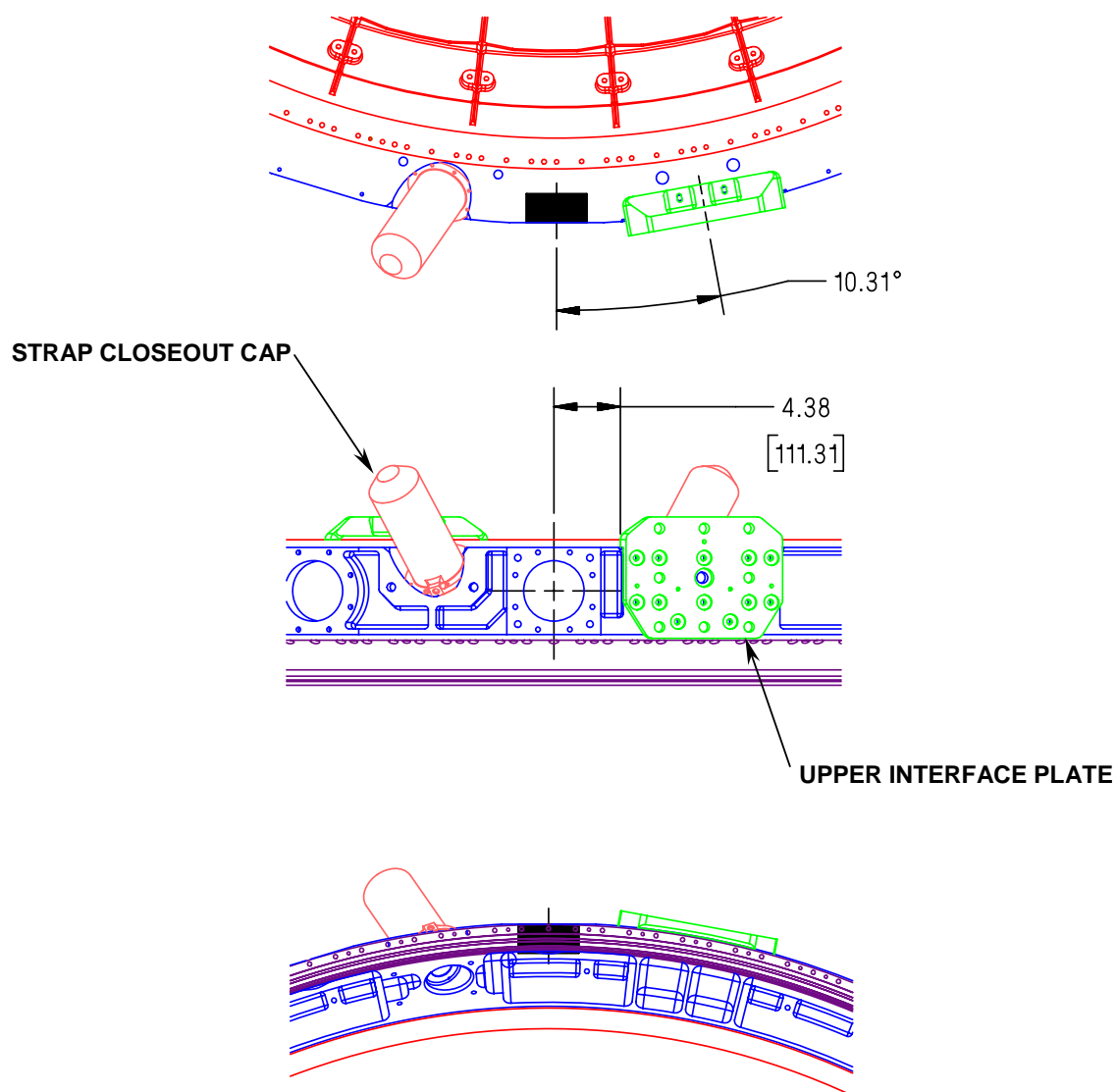


Figure 2.2.7-4 Cryo Service Port Layout

2.2.8 Keep In/Out Zones

Due to space station envelopes, shipping constraints and interfaces to other experiments, several keep in/out zones have been established. Figures 2.2.8-1 and 2.2.8-2 show the keep in zone for the cold mass hardware around the Upper and Lower Support Rings and for the MLI blankets that are protecting that hardware from the extreme environment. The keep in zones extend through the thickness of each Support Ring and include the strap closeout caps protruding out of the zone. Figures 2.2.8-1 through 2.2.8-4 also show the keep out zone for the Vacuum Case to USS-02 assembly. This area must remain clear until the Vacuum Case is installed. After that, cable routing can cross this area. The area between the Support Ring interface to the Outer Cylinder on both ends can also be used for cable routing and is shown in Figure 2.2.8-4. Figure 2.2.8-5 shows the cryocooler keep in zone for the locations outside of the USS-02. The keep in zone for the Cryo Service Port is shown in Figures 2.2.8-6 and 2.2.8-7. The keep in zone for the Cryo Service Port GSE is shown in Figures 2.2.8-8 and 2.2.8-9. This keep in zone will include both flight and ground configurations. Because of the numerous cable routings from all of the experiments, all cable routings and protrusions must be coordinated with ESCG, SCL, MIT and the TCS Group.

The Cryo magnet H/W is shown in Figures 2.2.8-10 and Figures 2.2.8-11.

All hardware that attaches to the VC must meet the requirements in the Thermal ICD.

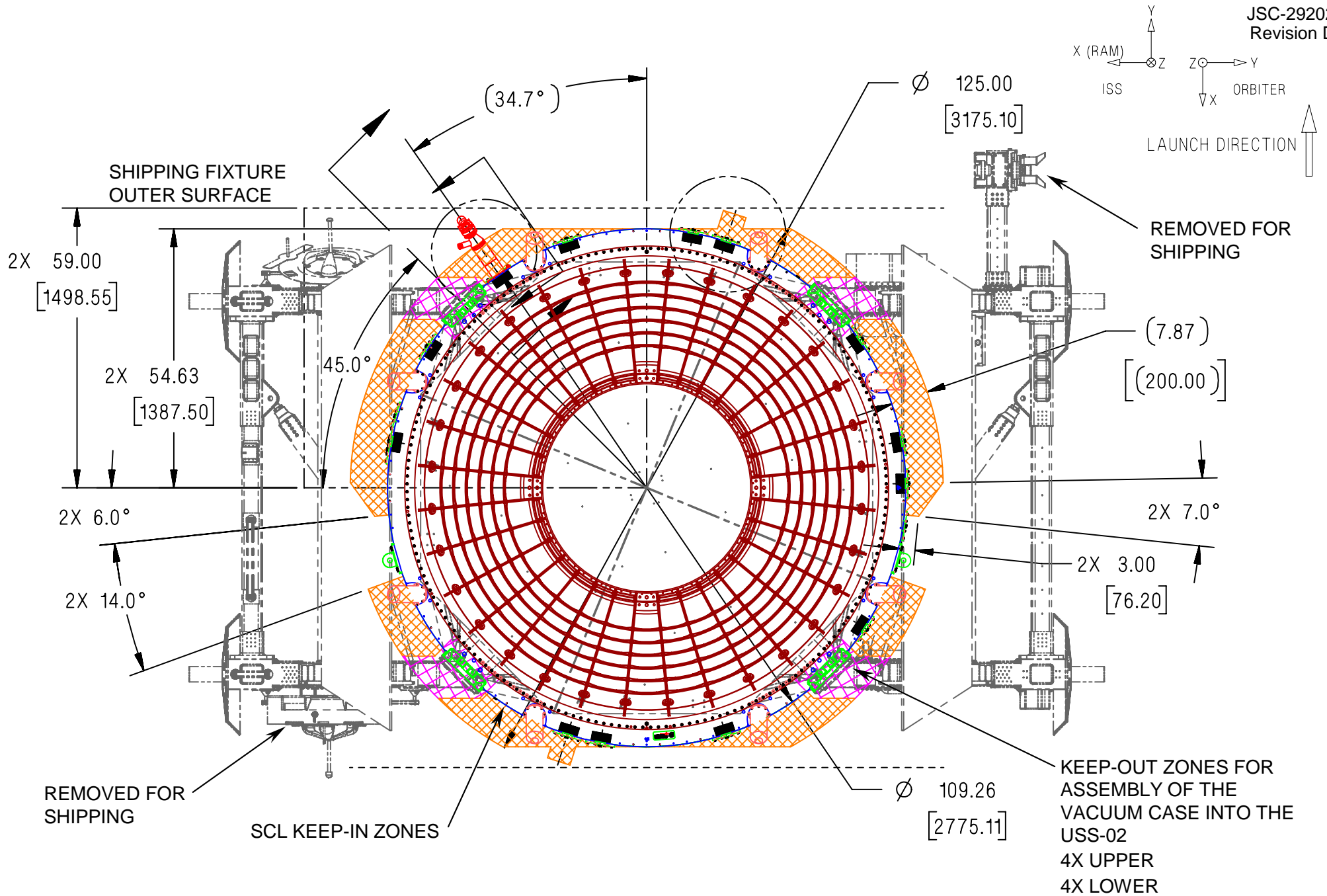


Figure 2.2.8-1 Keep In/Out Zones for the Upper Support Ring

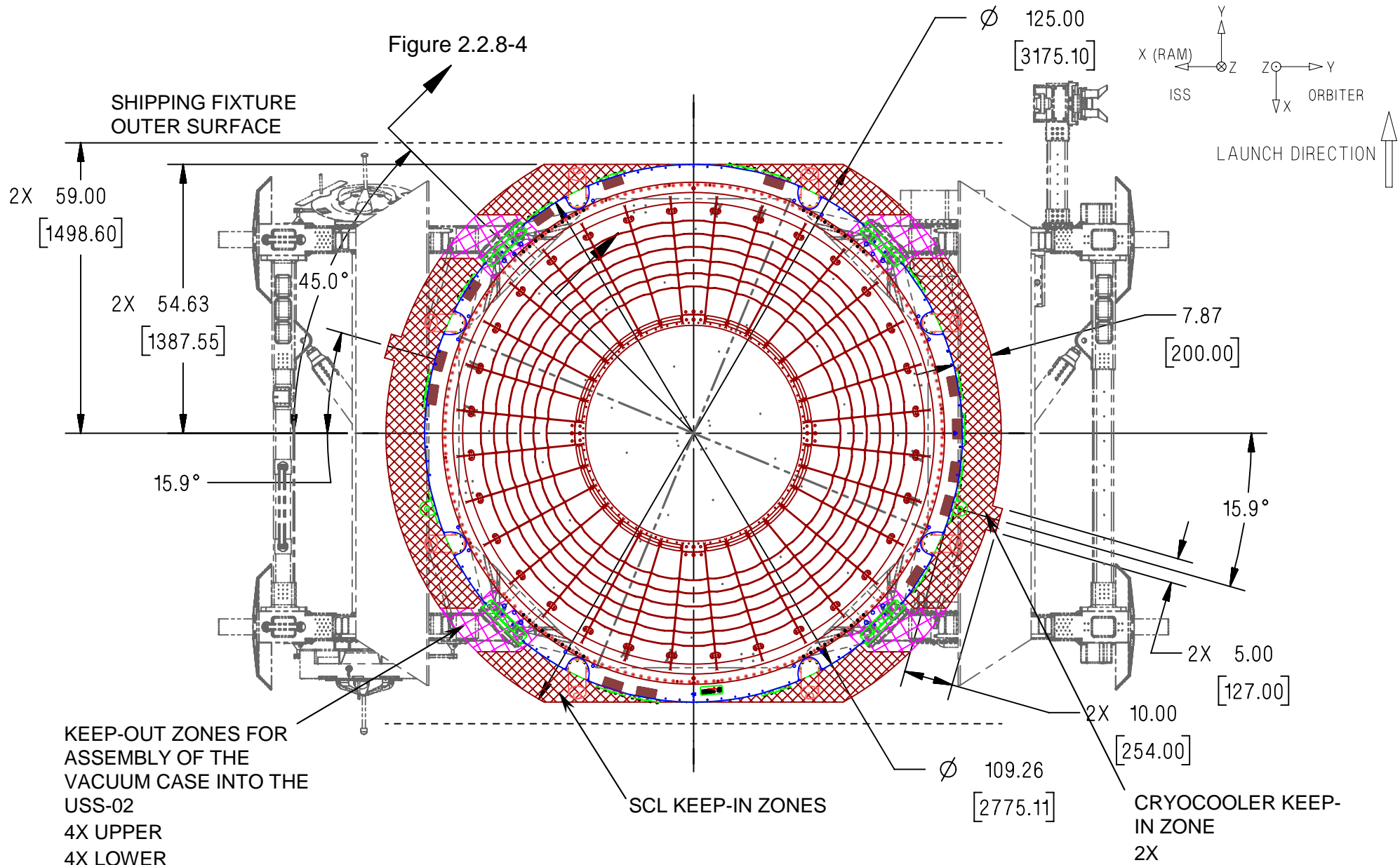


Figure 2.2.8-2 Keep In/Out Zones for the Lower Support Ring

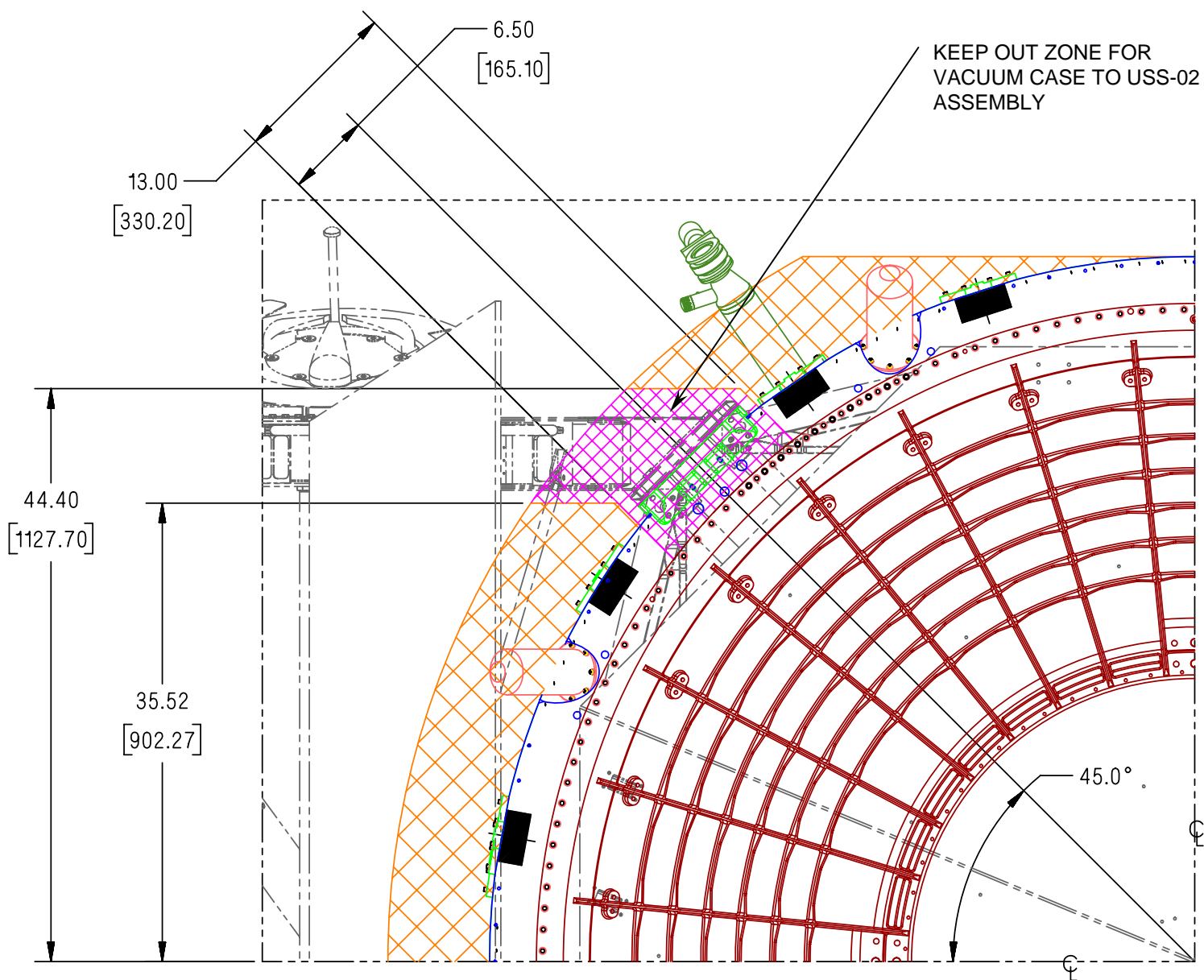


Figure 2.2.8-3 Detail View of the Keep Out Zone for the VC/USS-02 Assembly

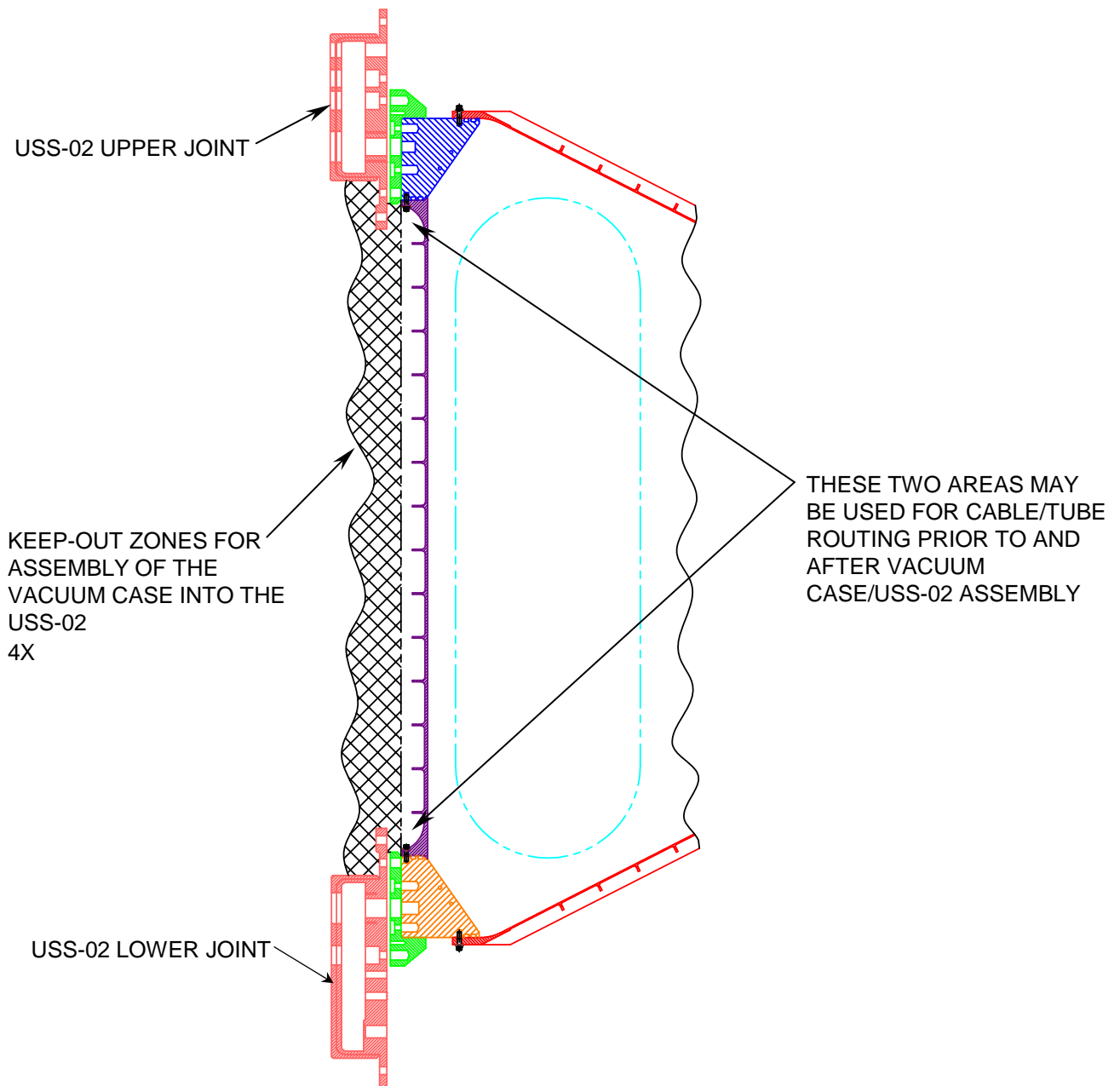


Figure 2.2.8-4 Section View of Keep Out Zone for the VC/USS-02 Assembly

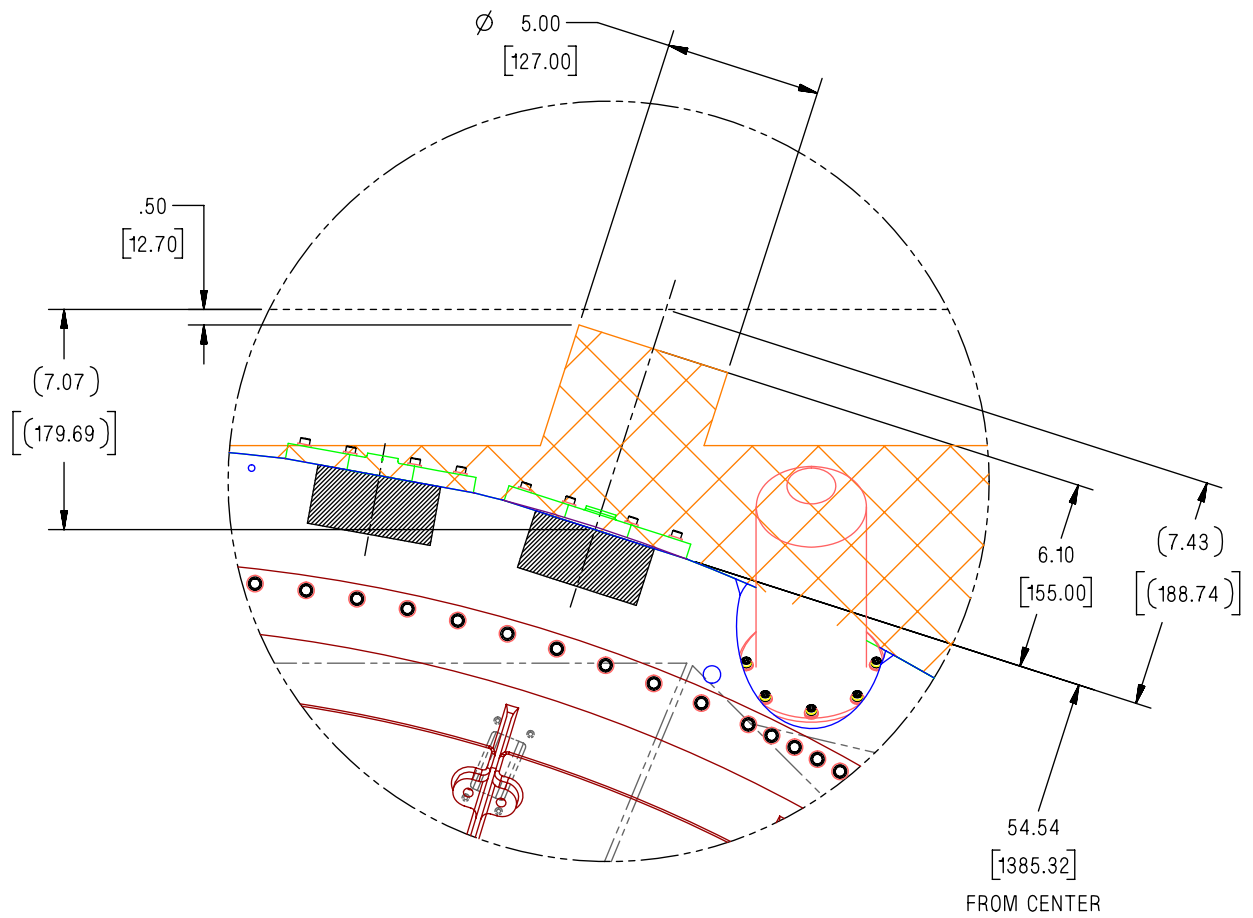


Figure 2.2.8-5 Keep In Zone for the Cryocoolers

Figure 2.2.8-7

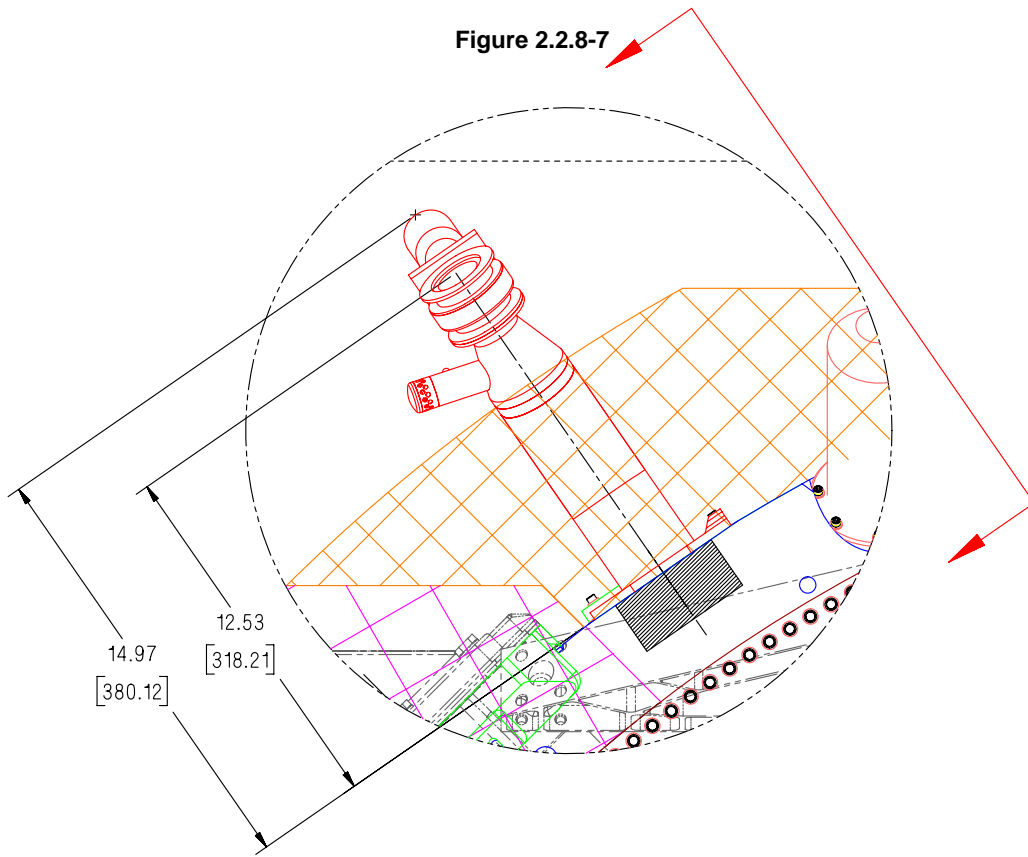


Figure 2.2.8-6 Keep In Zone for the Cryo Service Port Top View

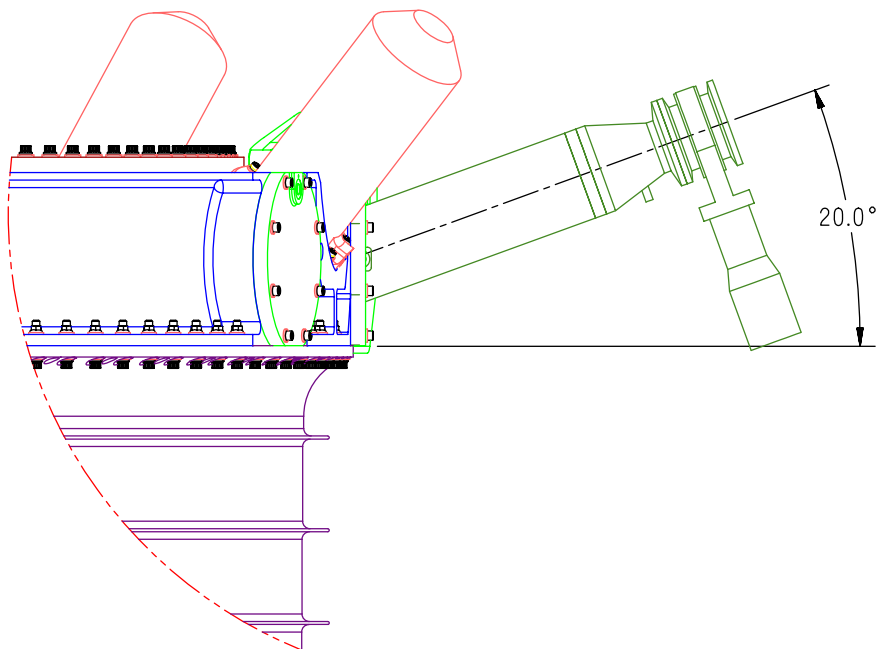


Figure 2.2.8-7 Keep In Zone for the Cryo Service Port Side View

Figure 2.2.8-9

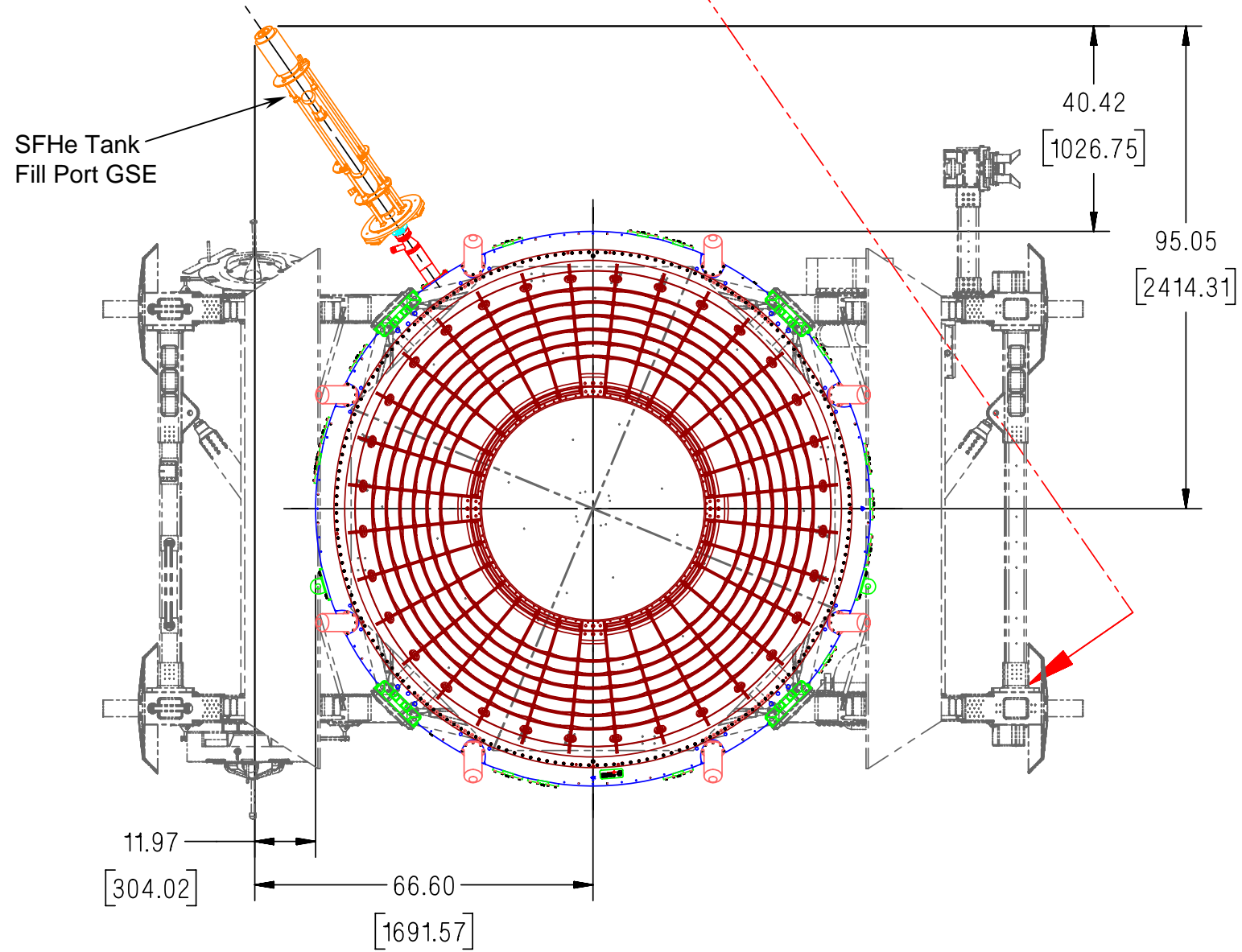


Figure 2.2.8-8 Keep In Zone for the Cryo Service Port GSE Top View

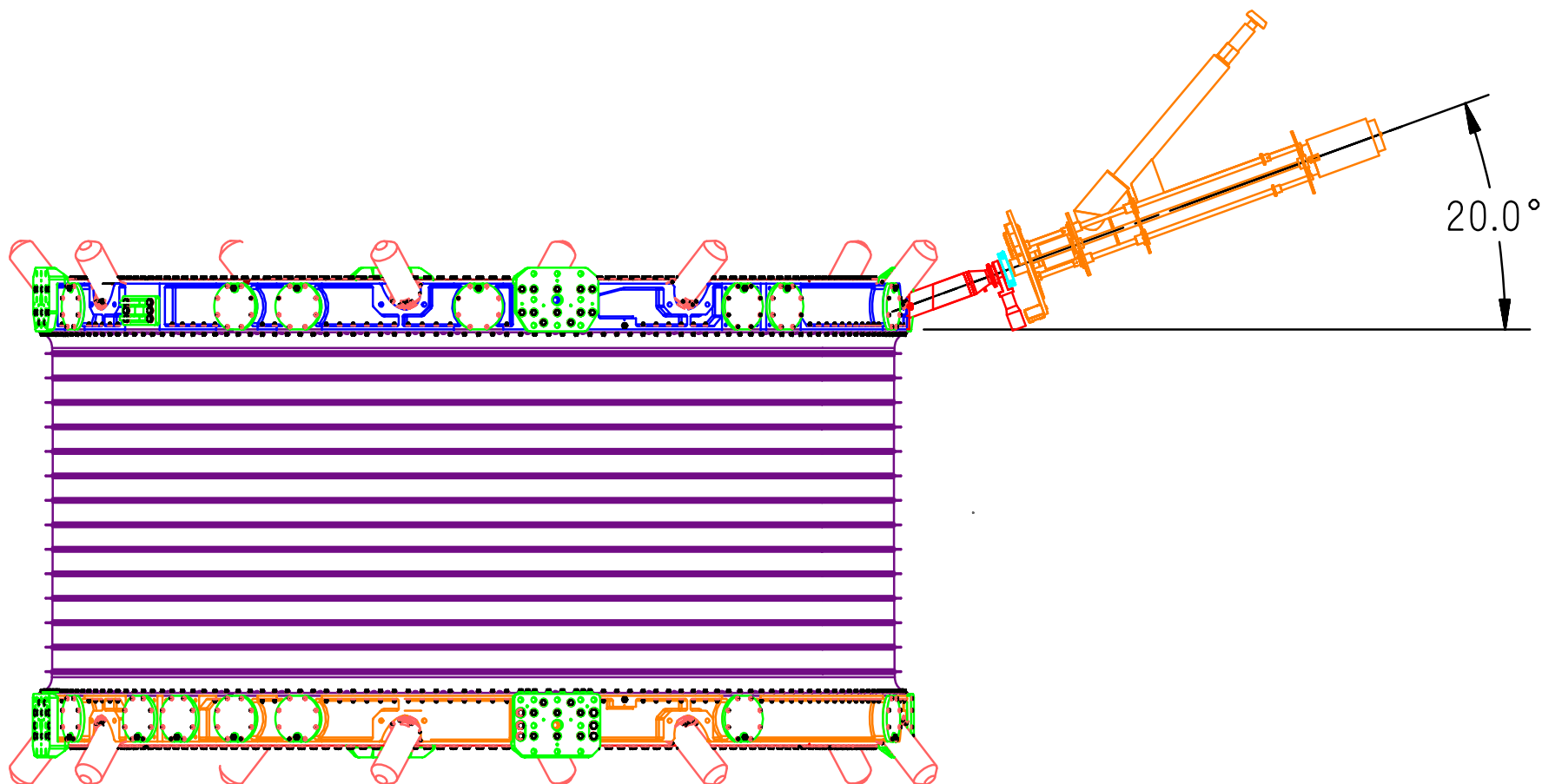
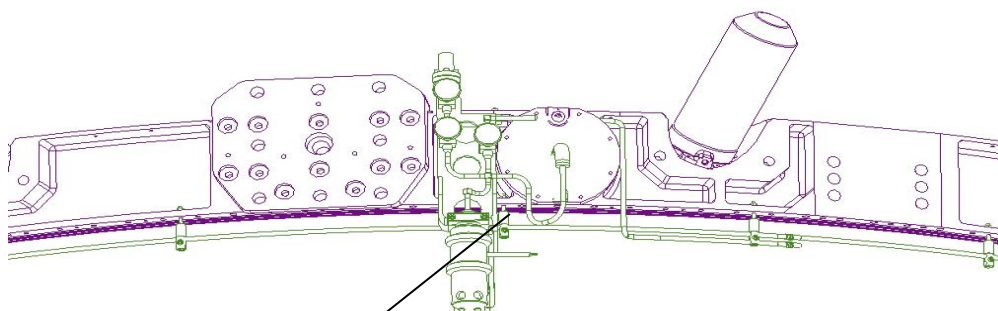


Figure 2.2.8-9 Keep In Zone for the Cryo Service Port GSE Side View



SUPERFLUID HE COOLING LOOP FILL

Figure 2.2.8-10 Upper Support Ring Magnet H/W (1 of 5)

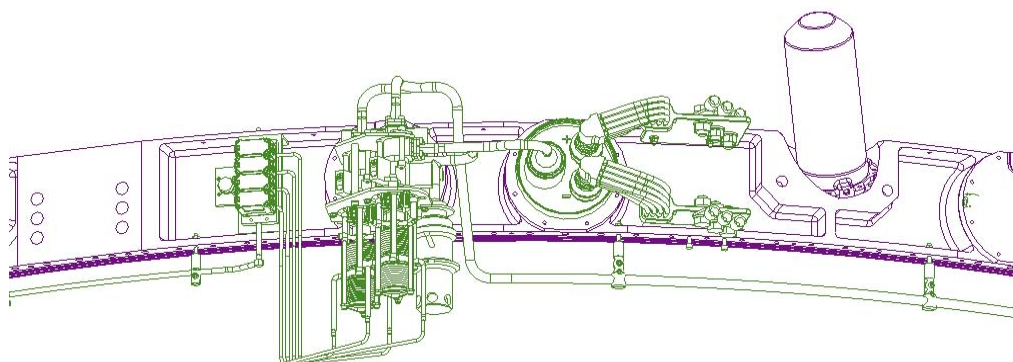


Figure 2.2.8-10 Upper Support Ring Magnet H/W (2 of 5)

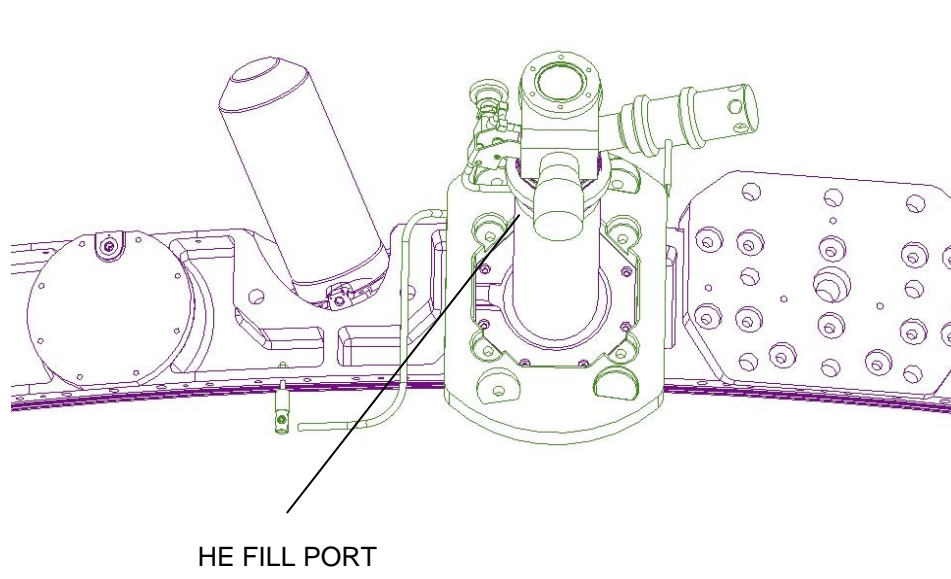


Figure 2.2.8-10 Upper Support Ring Magnet H/W (3 of 5)

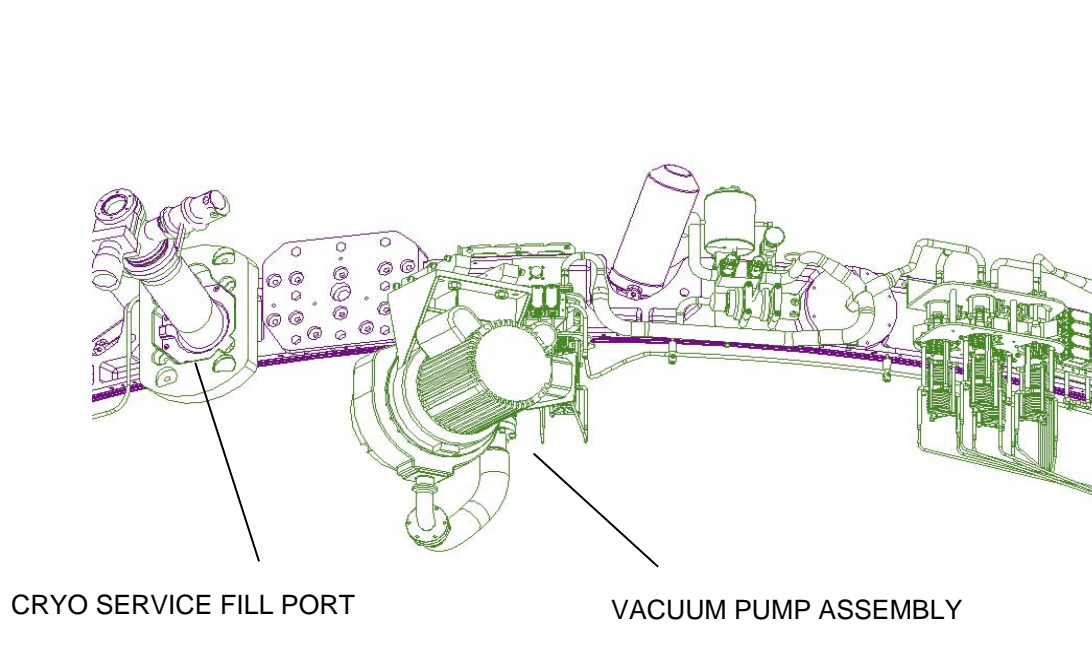


Figure 2.2.8-10 Upper Support Ring Magnet H/W (4 of 5)

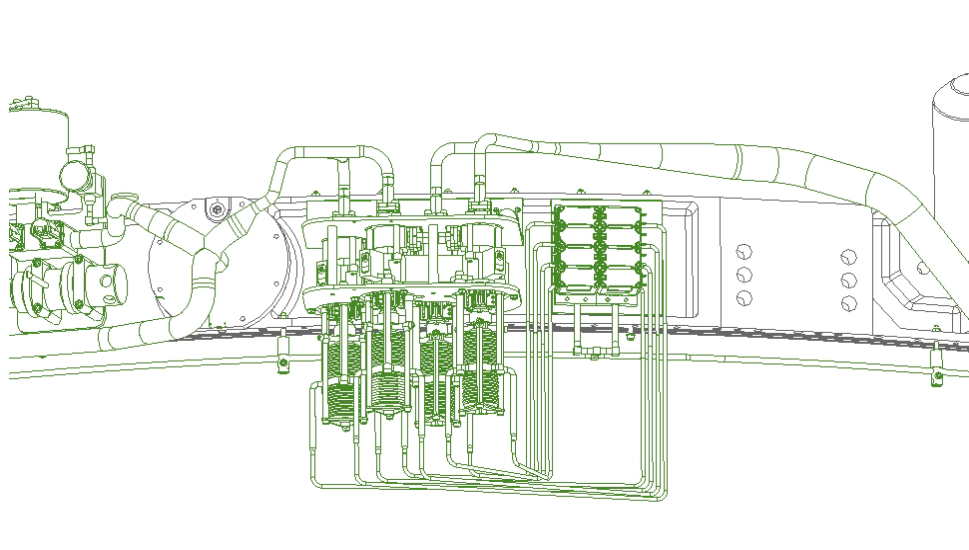


Figure 2.2.8-10 Upper Support Ring Magnet H/W (5 of 5)

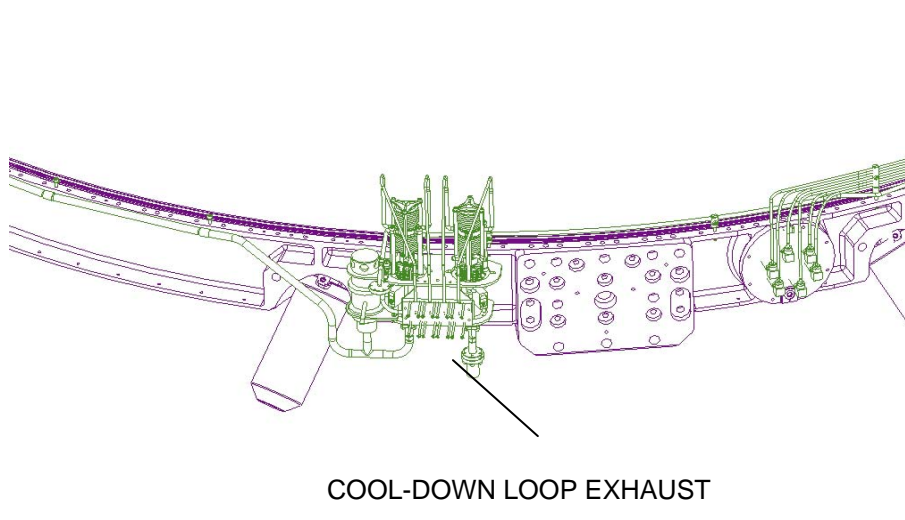
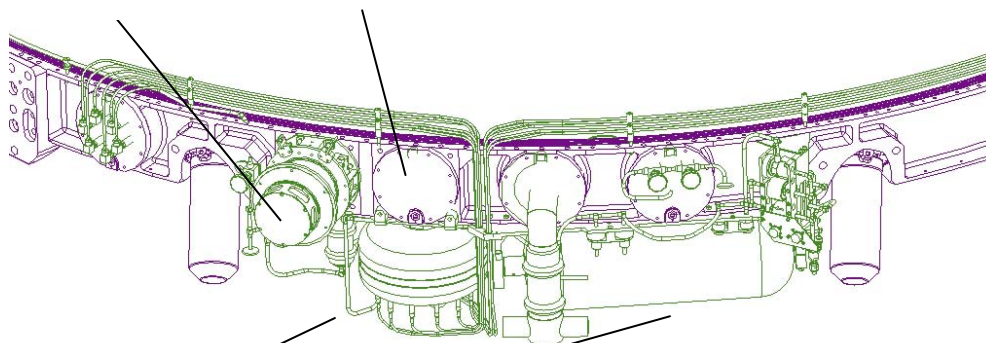


Figure 2.2.8-11 Lower Support Ring Magnet H/W (1 of 6)

CRYO COOLER AND CRYO COOLER ACCESS PORT



PVVV AND WARM HELIUM TANK

Figure 2.2.8-11 Lower Support Ring Magnet H/W (2 of 6)

5 WAY PILOT VALVE MANIFOLD

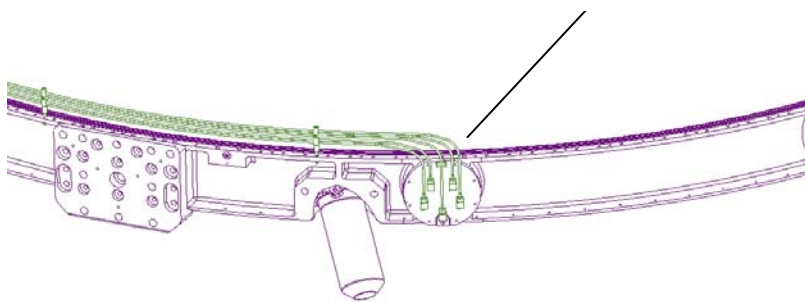


Figure 2.2.8-11 Lower Support Ring Magnet H/W (3 of 6)

VACUUM PUMP DOWN BUTTERFLY VALVE

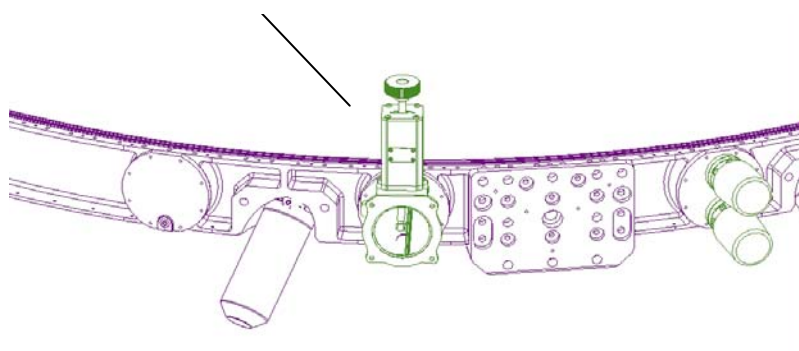


Figure 2.2.8-11 Lower Support Ring Magnet H/W (4 of 6)

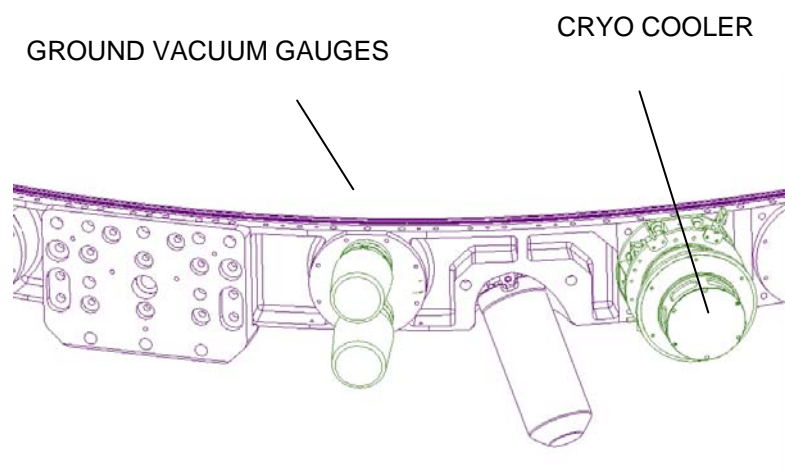


Figure 2.2.8-11 Lower Support Ring Magnet H/W (5 of 6)

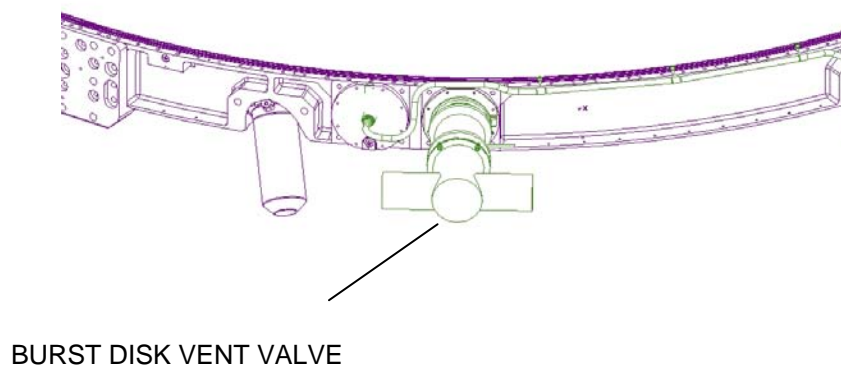


Figure 2.2.8-11 Lower Support Ring Magnet H/W (6 of 6)

2.2.9 Generic Bolt Pattern Interfaces on Inside of VC

Inside the Vacuum Case Upper and Lower Support Rings, a generic hole pattern has been incorporated, as shown in Figure 2.2.9-1, to allow the AMS-02 experiment team to mount additional lightweight hardware internal to the vacuum space. The pattern consists of numerous inserts for #10 bolts. The maximum allowable load for each of these #10 bolts is 10 lb under a 1g acceleration in each axis. The pattern includes a bolt approximately every 6 inches around the circumference on both the top and bottom ring. There are additional bolt inserts near the strap feed-thru ports as shown in Figures 2.2.9-2 through 2.2.9-4.

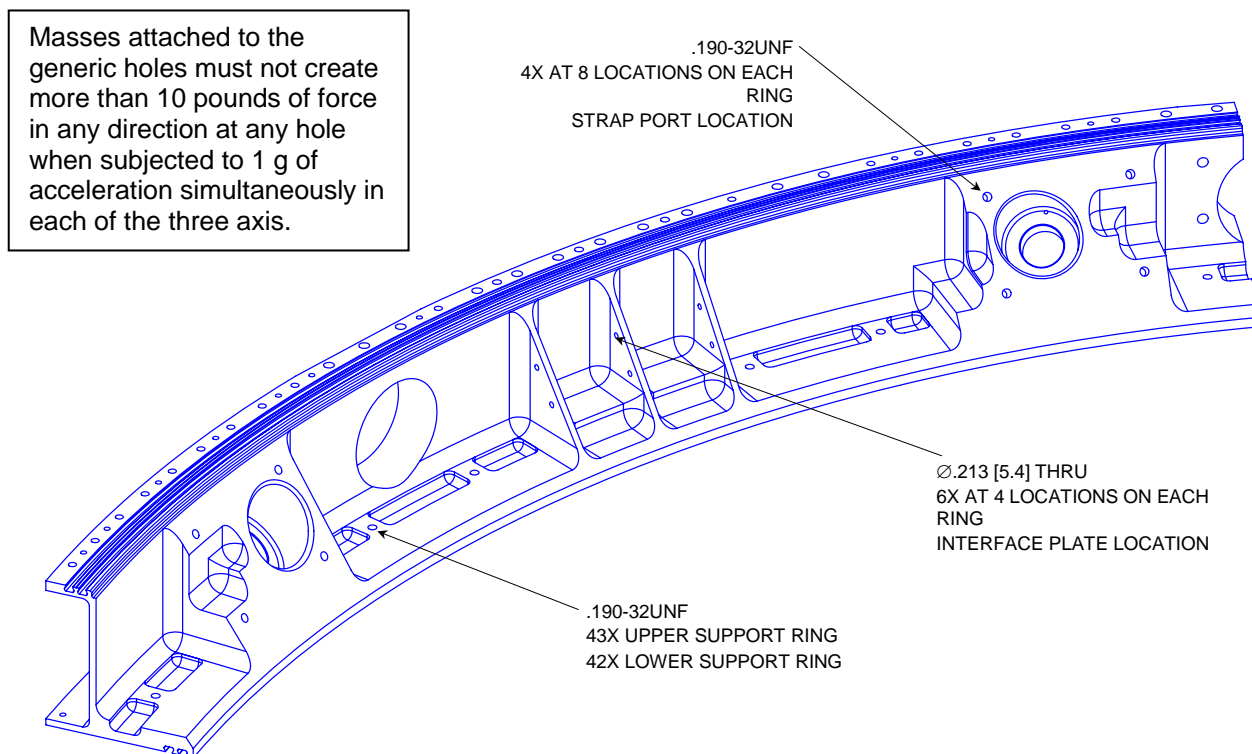


Figure 2.2.9-1 ISO View Section of Generic Holes for CM

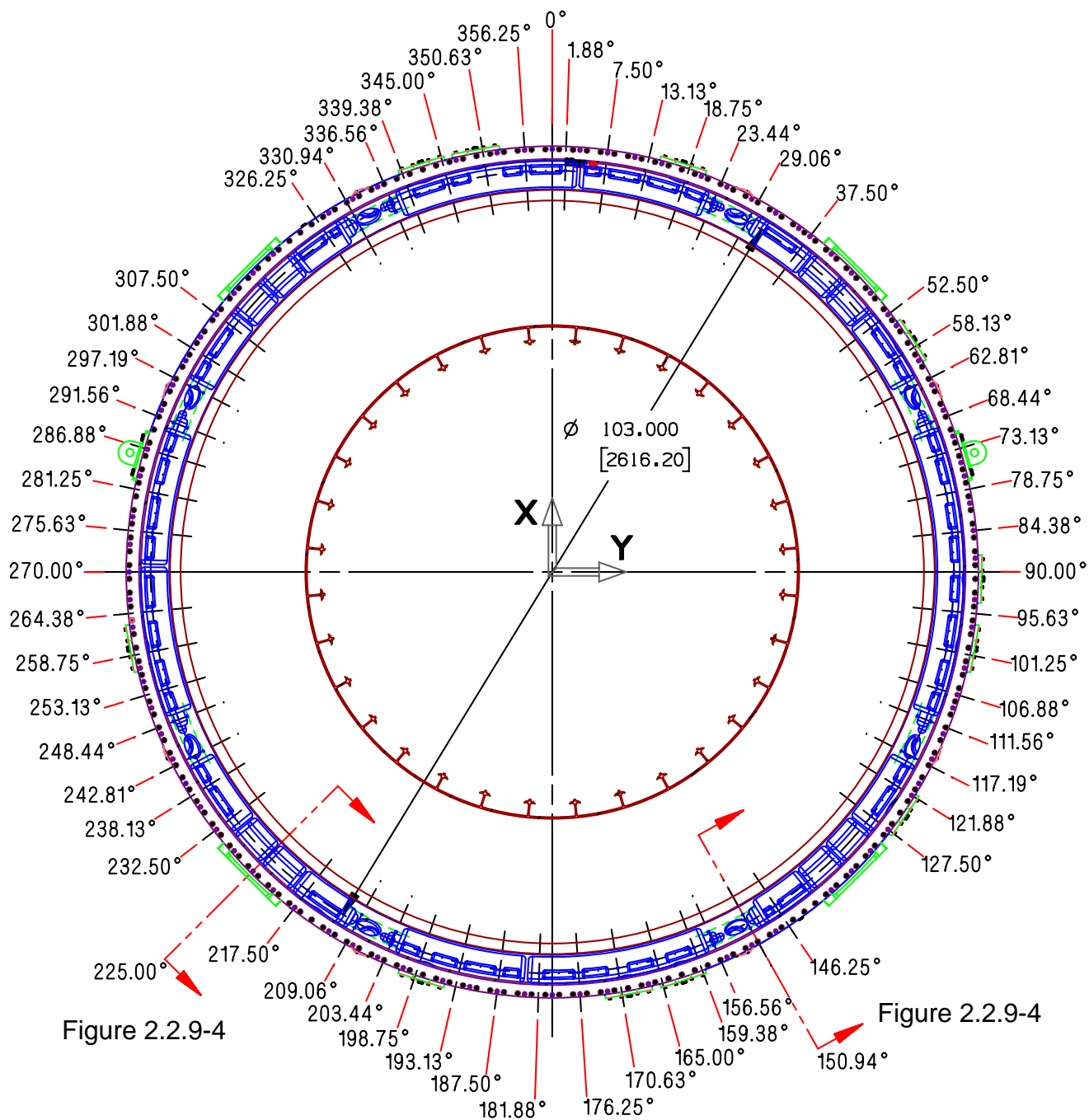


Figure 2.2.9-2 Upper Support Ring Generic Hole Pattern for CM

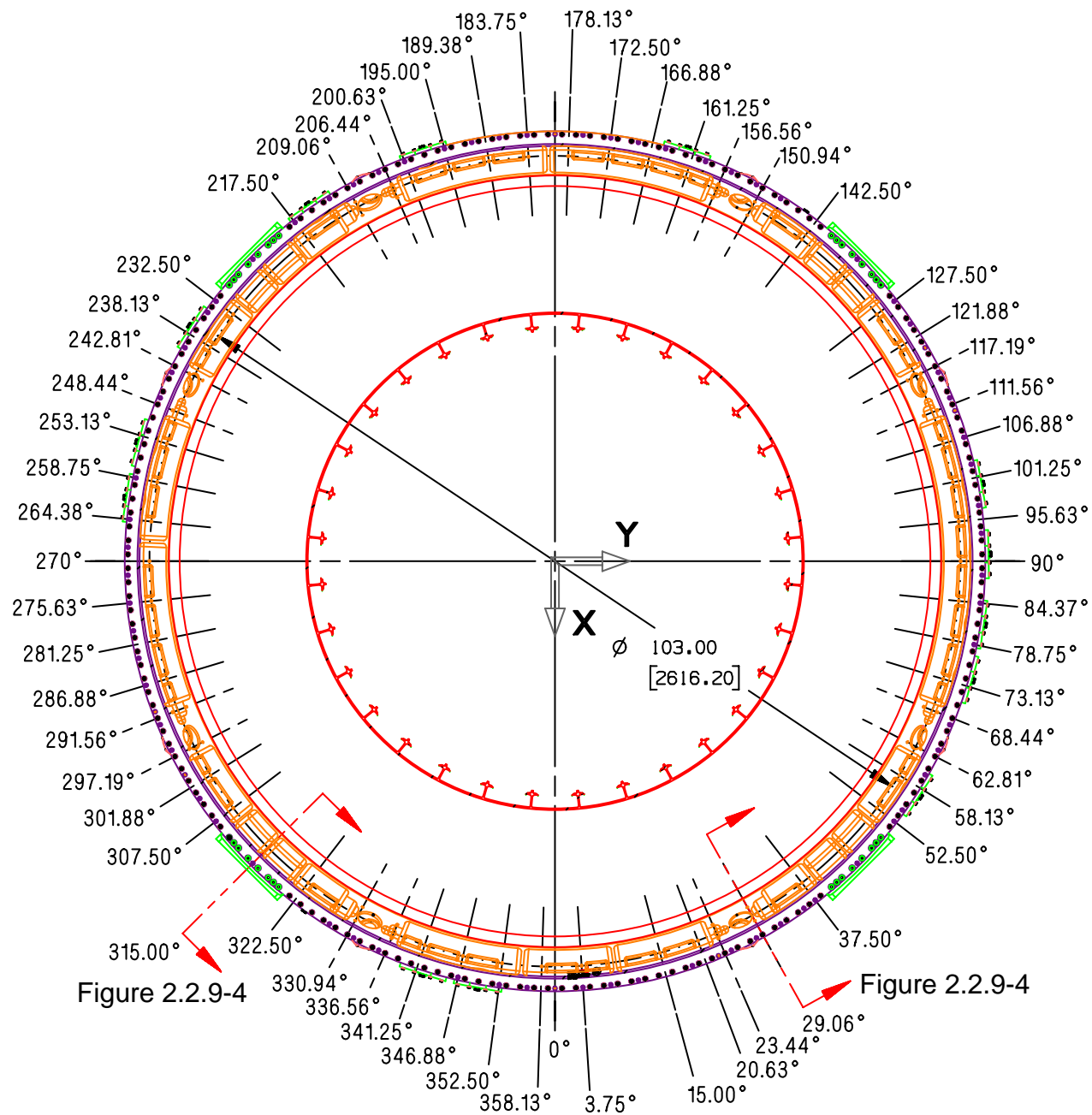


Figure 2.2.9- 3 Lower Support Ring Generic Hole Pattern for CM

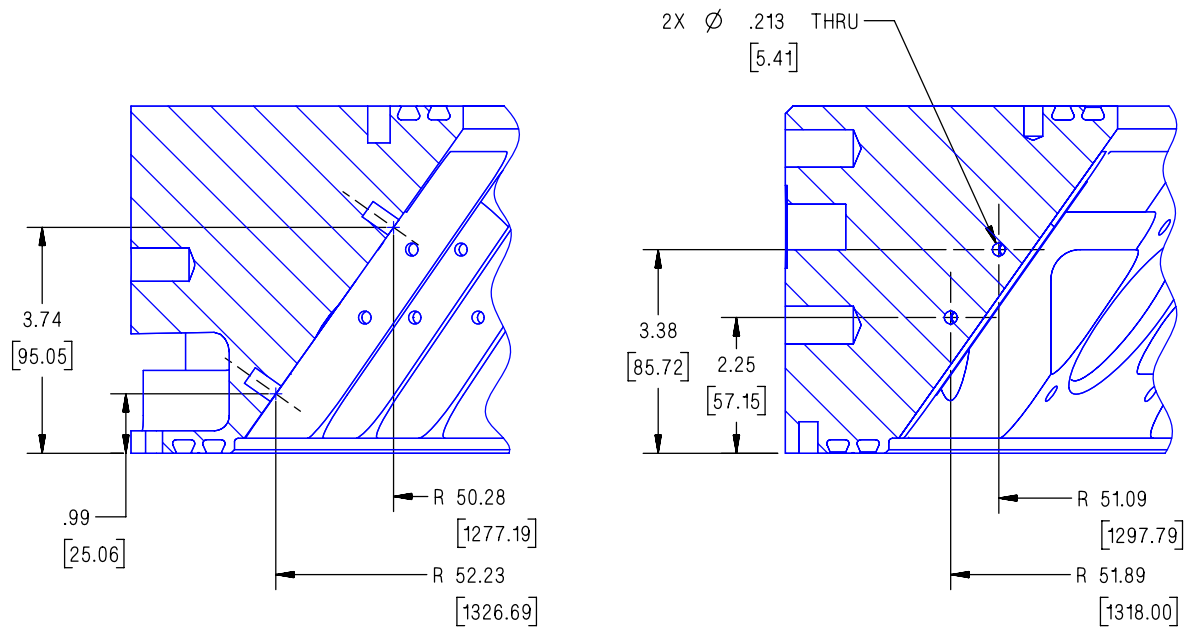


Figure 2.2.9-4 Detail Views of Generic Hole Pattern for CM

2.2.10 GSE Holes at Strap Locations

A set of holes has been incorporated on the outside of the VC around each strap port. These holes are for supporting the strap preload operation during the installation of the CM into the VC. These holes are in addition to the holes that are located on the strap closeout cap mating surface. Figures 2.2.10-1 through 2.2.10-4 detail these hole locations.

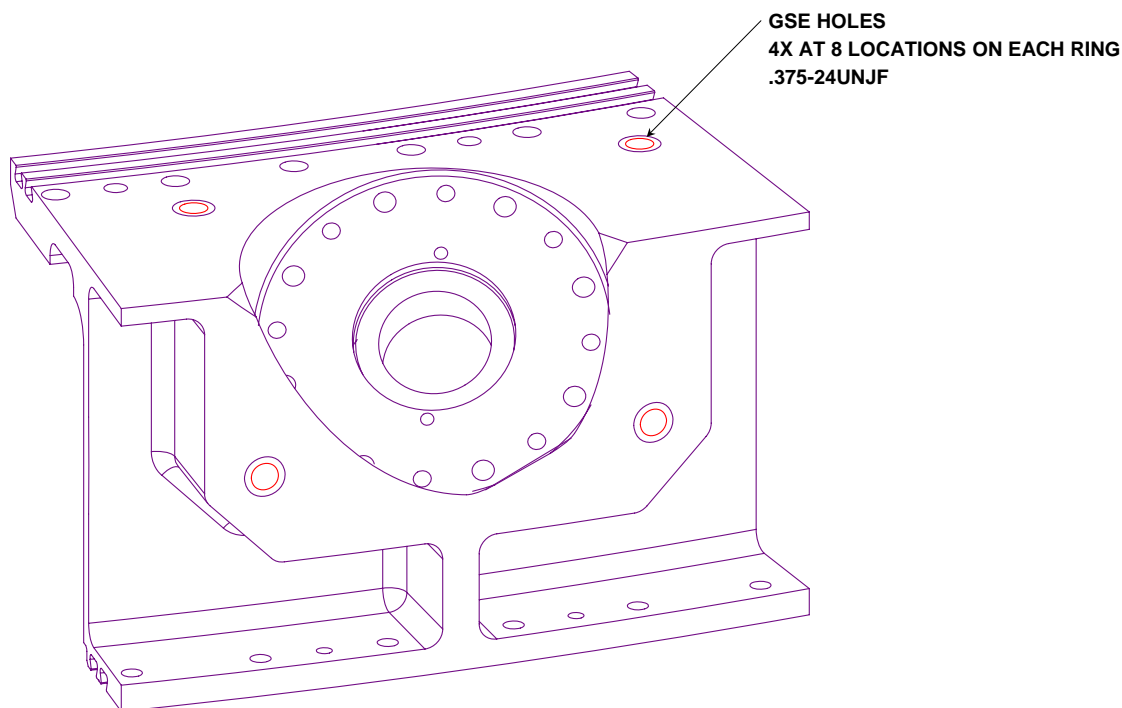


Figure 2.2.10-1 ISO View of Strap GSE Holes

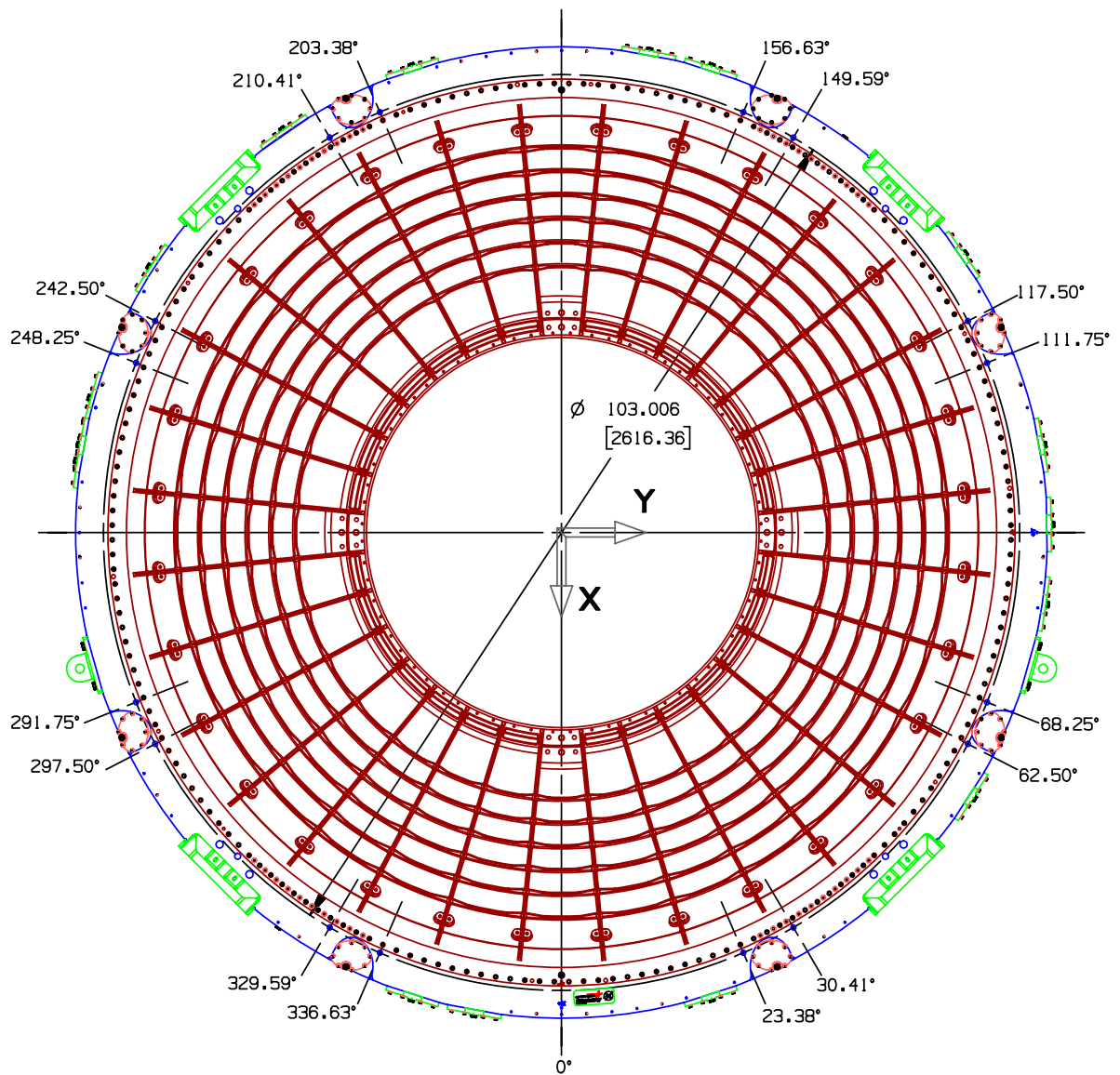


Figure 2.2.10-2 Top/Bottom View of Hole Locations

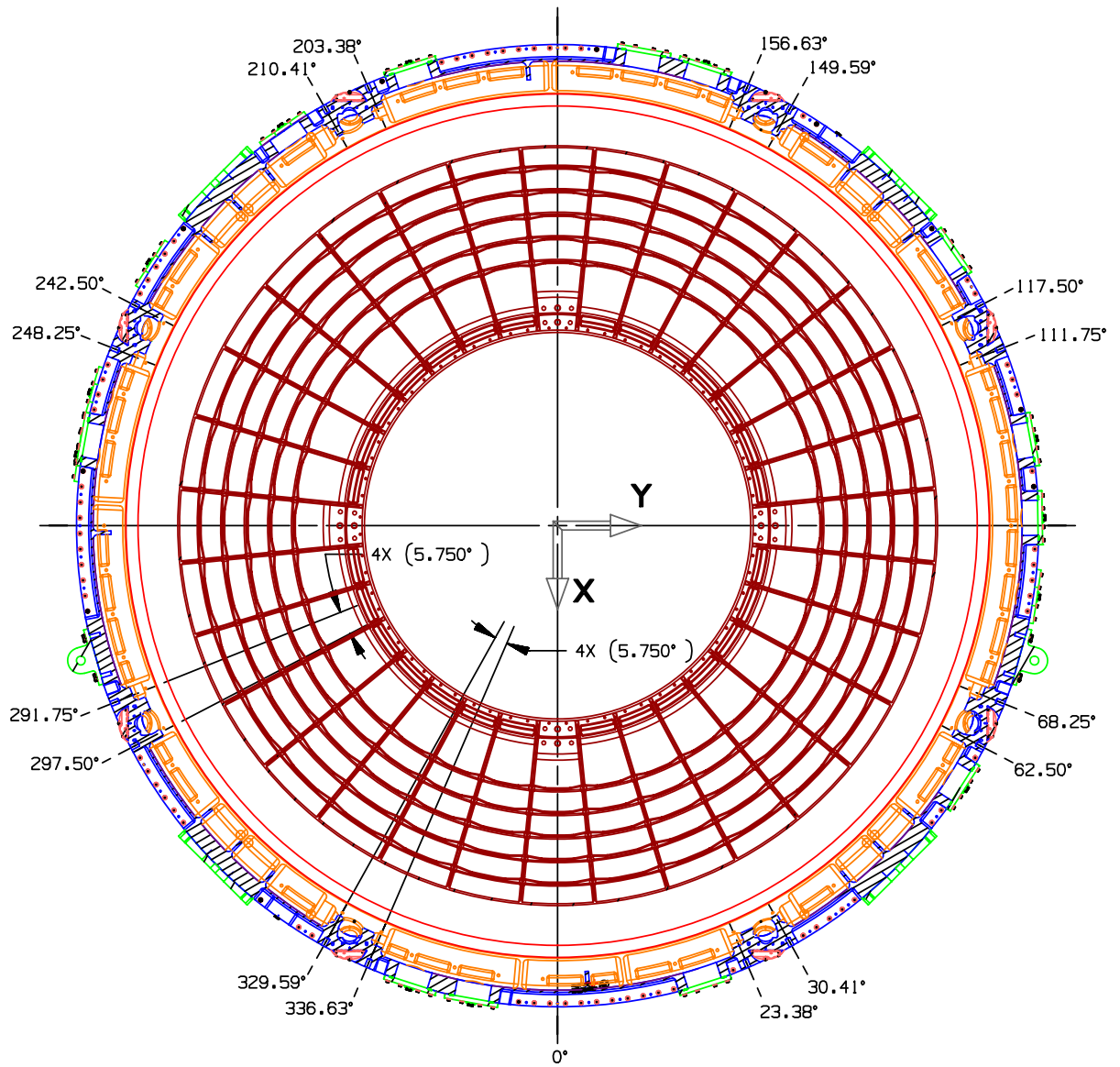


Figure 2.2.10-3 Section View of Side Hole Locations

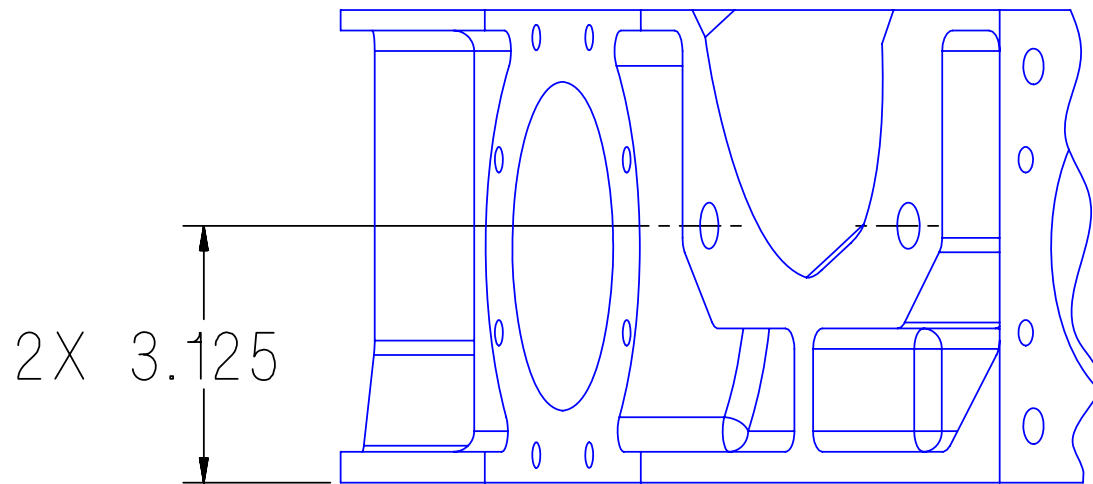


Figure 2.2.10-4 Detail View of Side Holes

2.2.11 Experiment Interfaces to Vacuum Case

The Tracker and Anti-Coincidence Counter mount to the inner diameter of the Vacuum Case Conical Flanges. An ISO view section of the Conical Flange with the interfaces is shown in Figure 2.2.11-1.

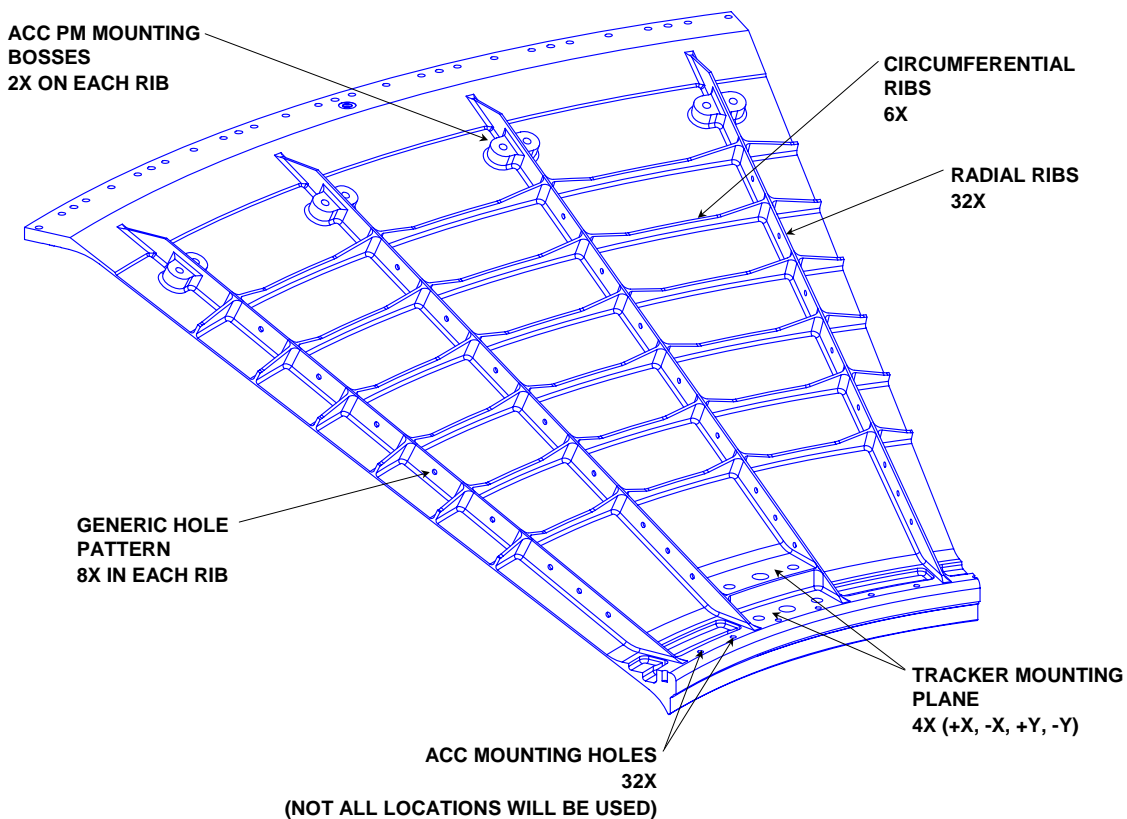
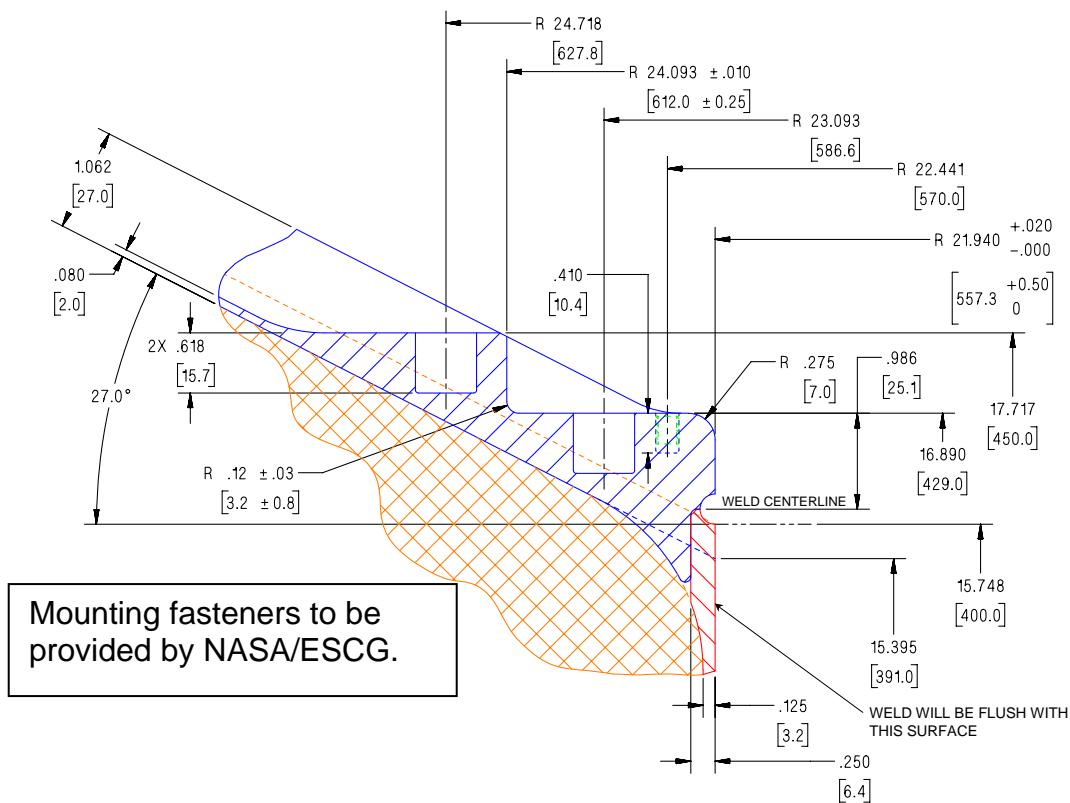
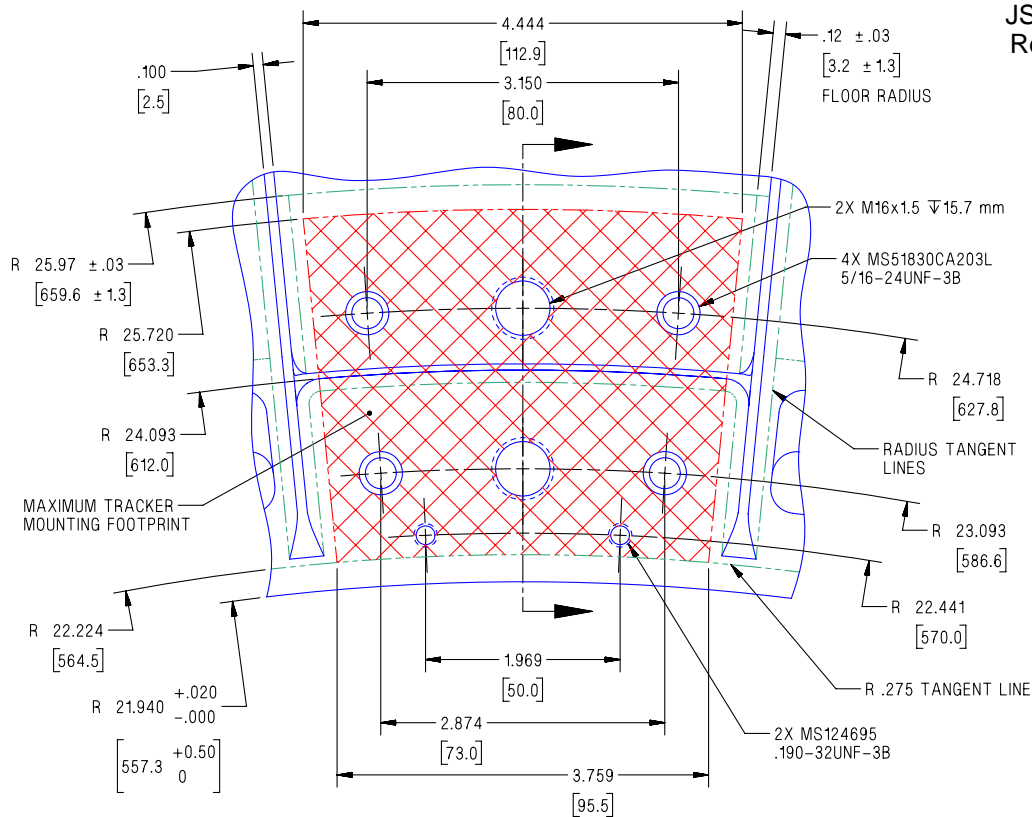


Figure 2.2.11-1 ISO View Showing Experiment Interfaces on Conical Flange

2.2.11.1 Tracker Support Feet

The Tracker Support Feet are mounted to the Vacuum Case as shown in Figures 2.2.11.1-1 and 2.2.11.1-2.



2.2.11.2 Anti-Coincidence Counter Support Feet

The ACC support feet mount to the inner diameter of the upper and lower conical flanges of the Vacuum Case. These mounting locations are shown in Figure 2.2.11.2-1. The hole pattern shown in Figure 2.2.11.2-1 exists between each of the conical flange ribs, but the ACC will only utilize the pattern between every other pocket. The additional bolt inserts can be used for other mounting as required by the experiment.

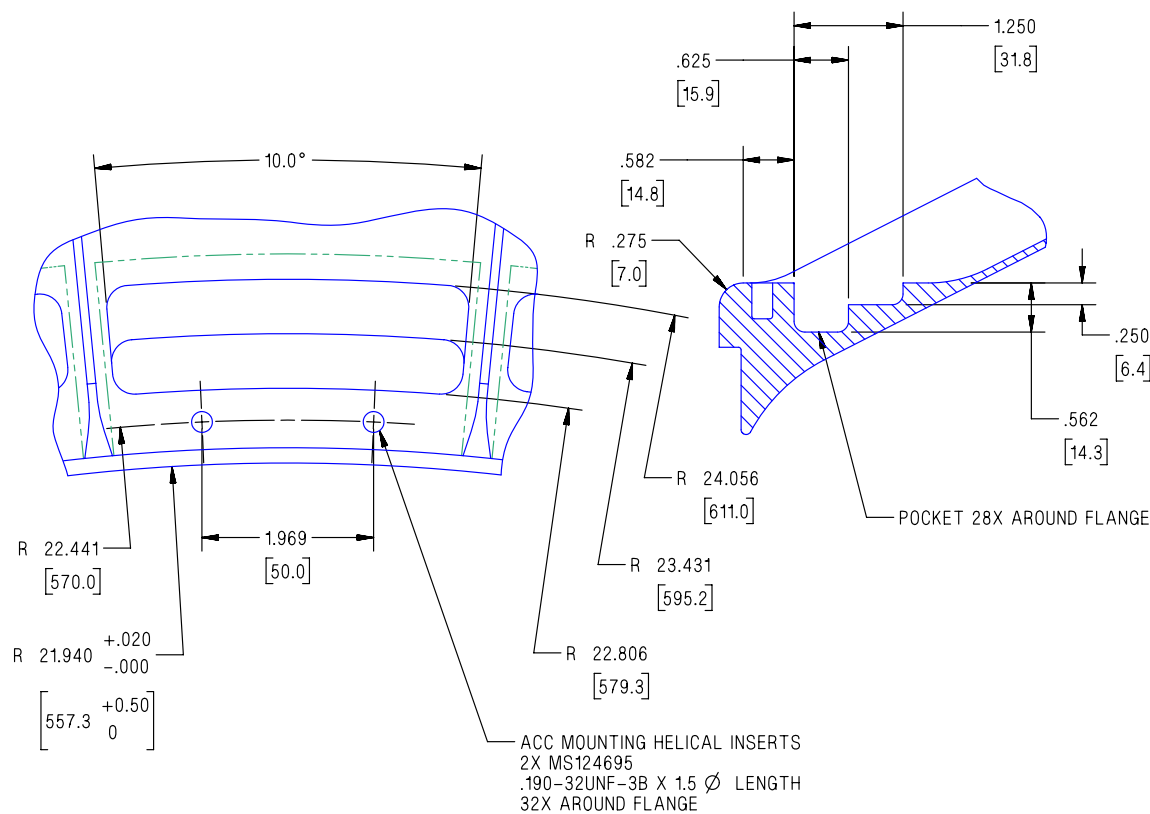


Figure 2.2.11.2-1 ACC Mounting Pattern

2.2.11.3 Generic Bolt Pattern Interfaces on Outside of VC

A generic bolt hole pattern exists on the Vacuum Case Conical Flange Ribs as shown in Figure 2.2.11.3-1. The maximum allowable force on each hole is 4.5 lbf. Additional generic bolt hole patterns will be incorporated into the upper and lower rings of the VC as shown in Figures 2.2.11.3-2 through 2.2.11.3-6. The maximum allowable force on each hole is 16 lbf. This pattern includes numerous #10 bolt inserts and thru holes at approximately 3 inch spacing around the circumference of both the upper and lower support rings and the upper and lower outer cylinder mating flanges. The allocation/sharing of the holes shall be controlled by a hole database under the configuration control of the AMS-02 Mechanical Integration Team at CERN.

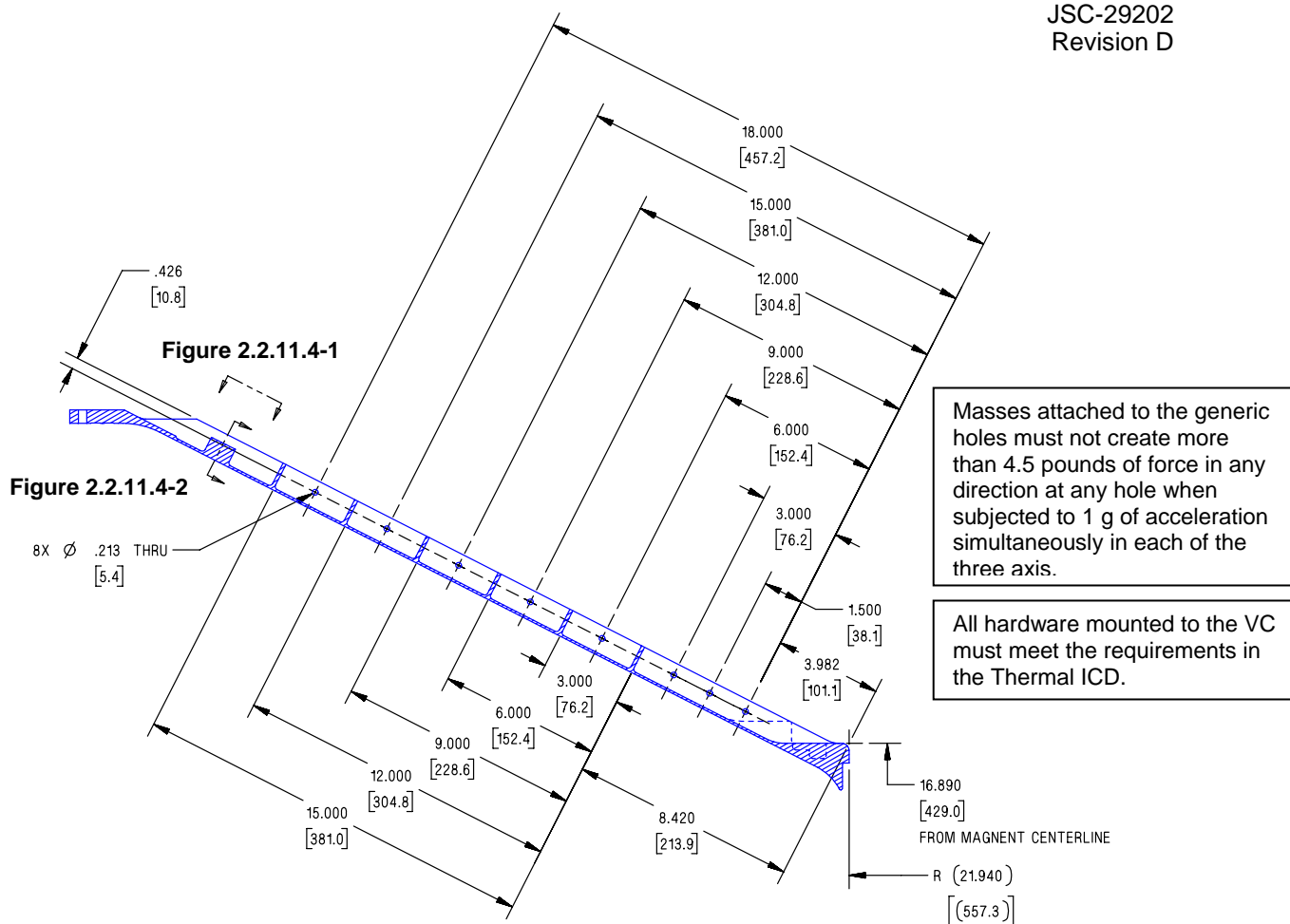


Figure 2.2.11.3-1 Generic Bolt Hole Pattern on Conical Flange Ribs

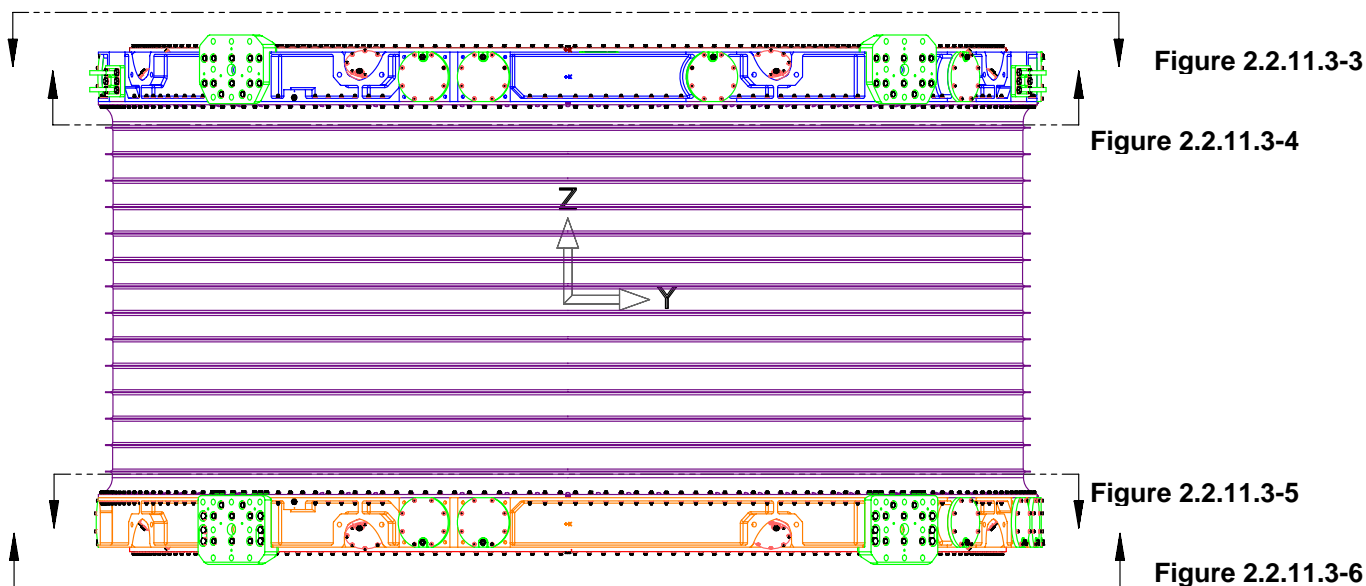


Figure 2.2.11.3-2 Generic Bolt Hole Pattern on Vacuum Case

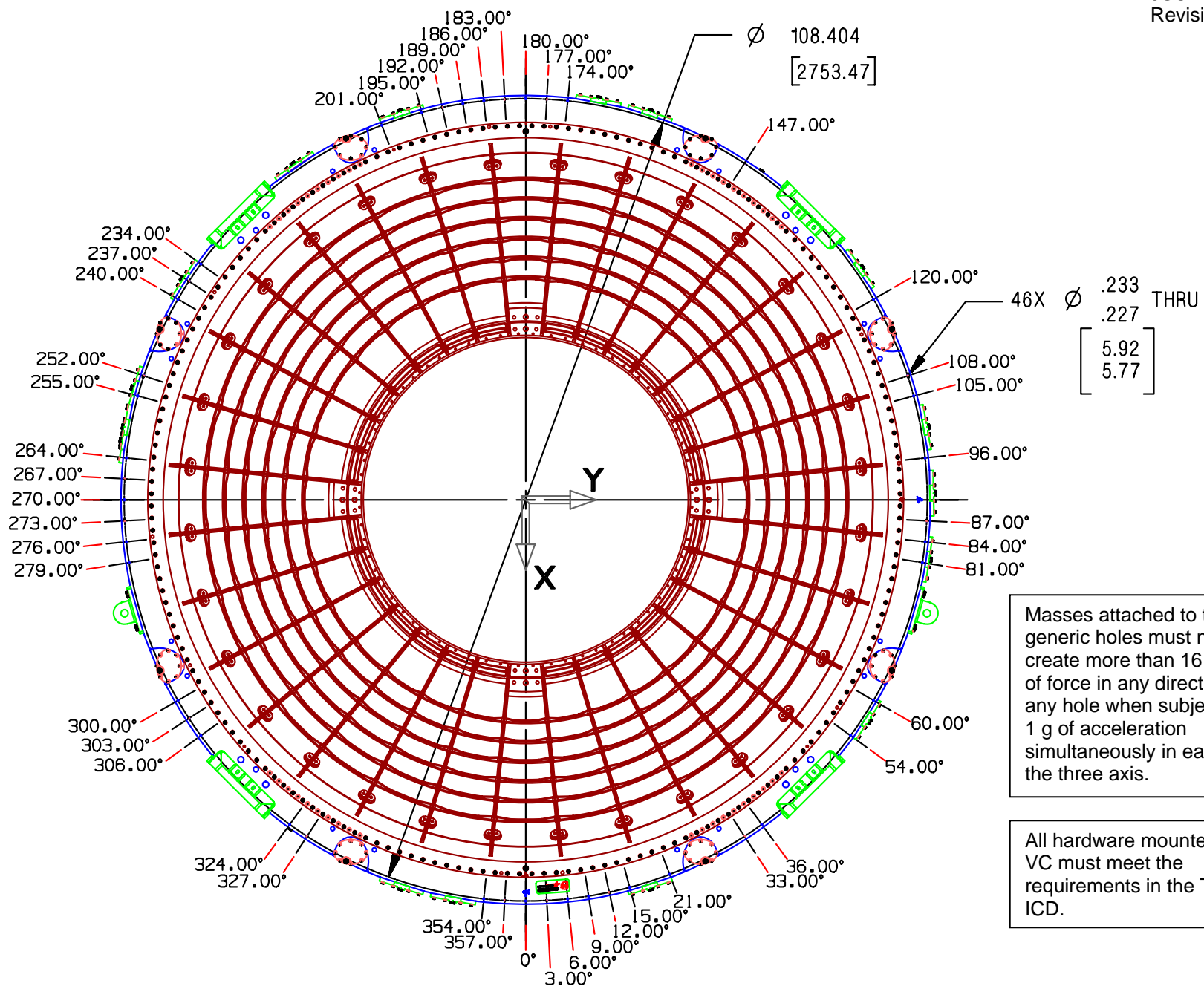


Figure 2.2.11.3-3 Generic Bolt Hole Pattern on VC Upper Support Ring

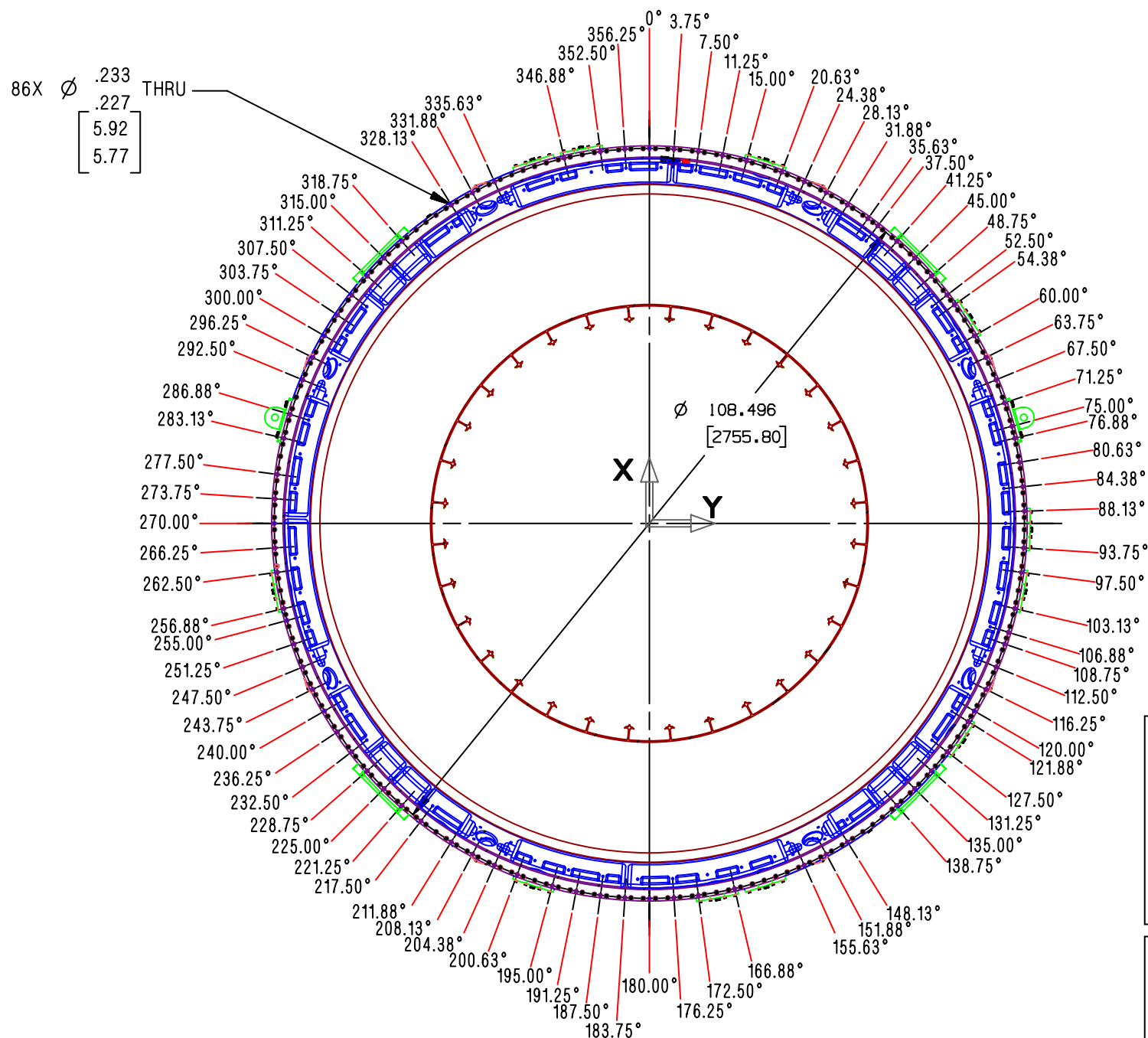


Figure 2.2.11.3-4 Generic Bolt Hole Pattern on VC Outer Cylinder Upper Flange

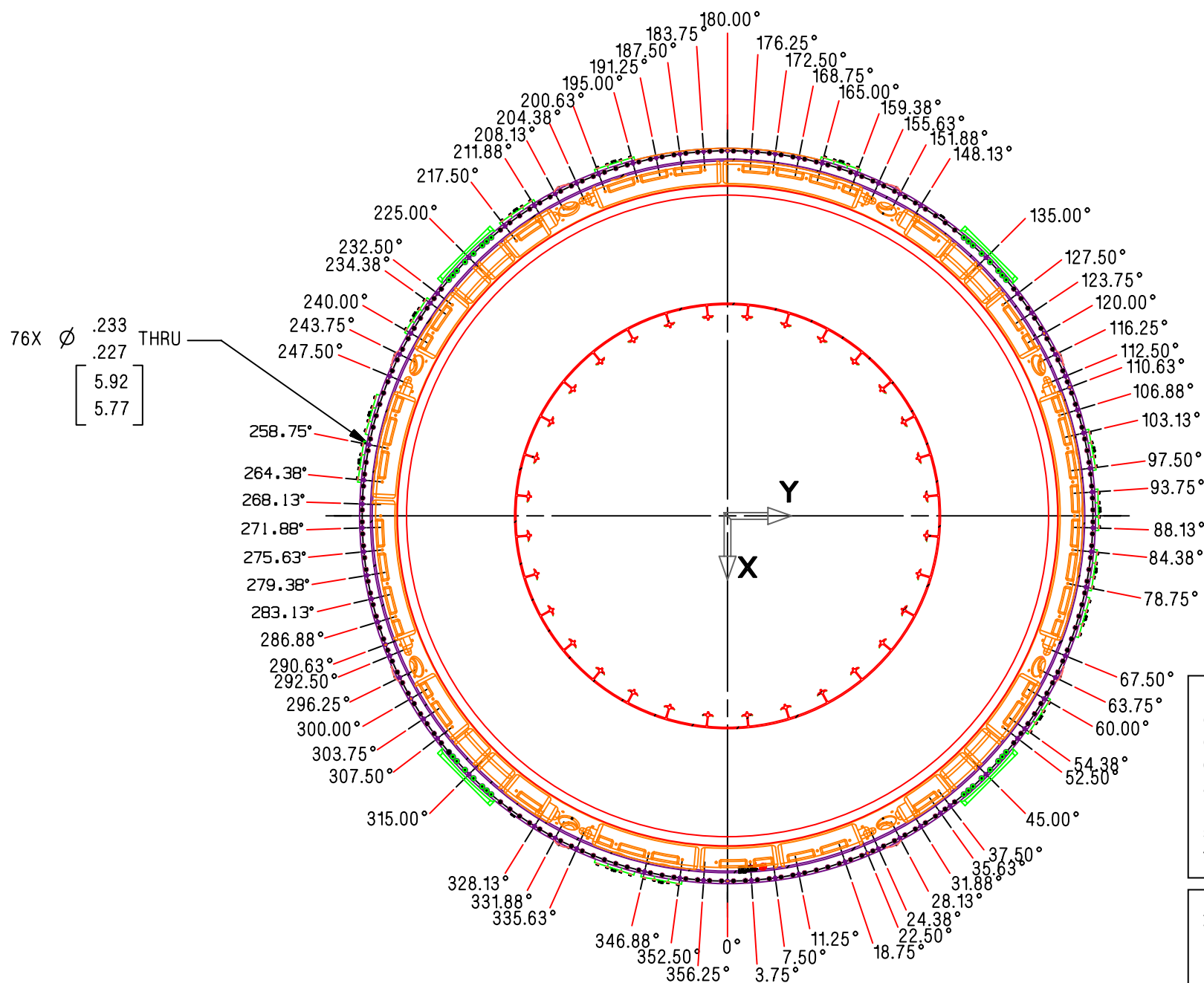


Figure 2.2.11.3-5 Generic Bolt Hole Pattern on VC Outer Cylinder Lower Flange

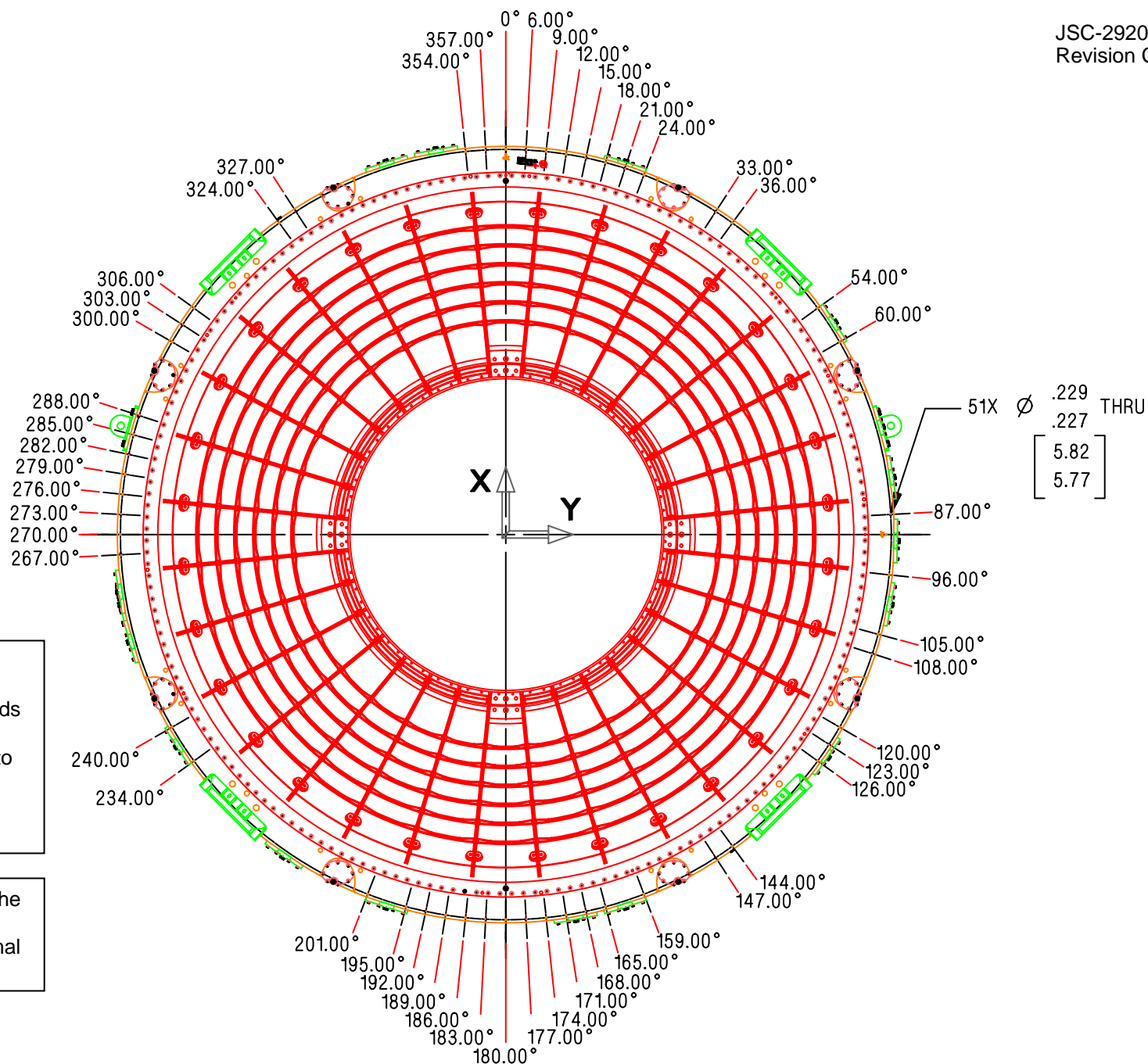


Figure 2.2.11.3-6 Generic Bolt Hole Pattern on VC Lower Support Ring

2.2.11.4 Anti-Coincidence Counter Photomultiplier Mounts

The ACC photomultipliers mount to the top and bottom conical flanges at the PM mounted locations as shown in Figure 2.2.11.4-1.

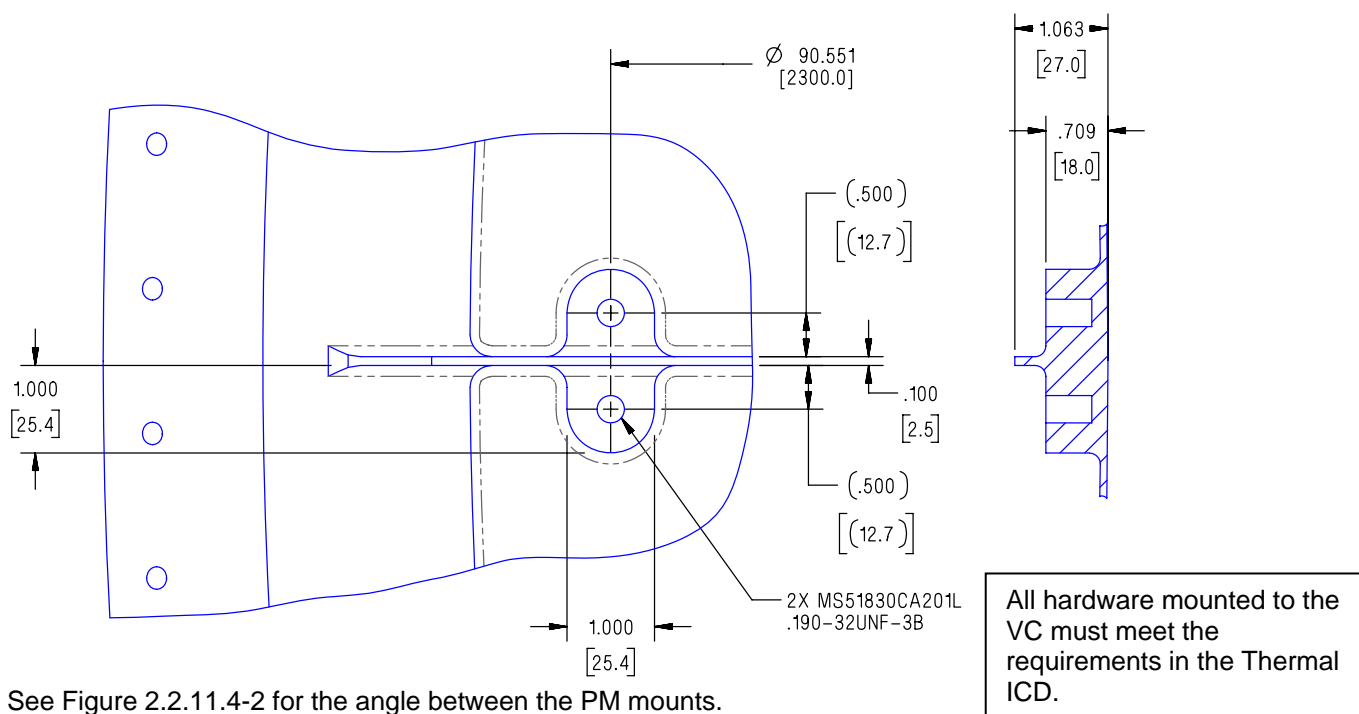
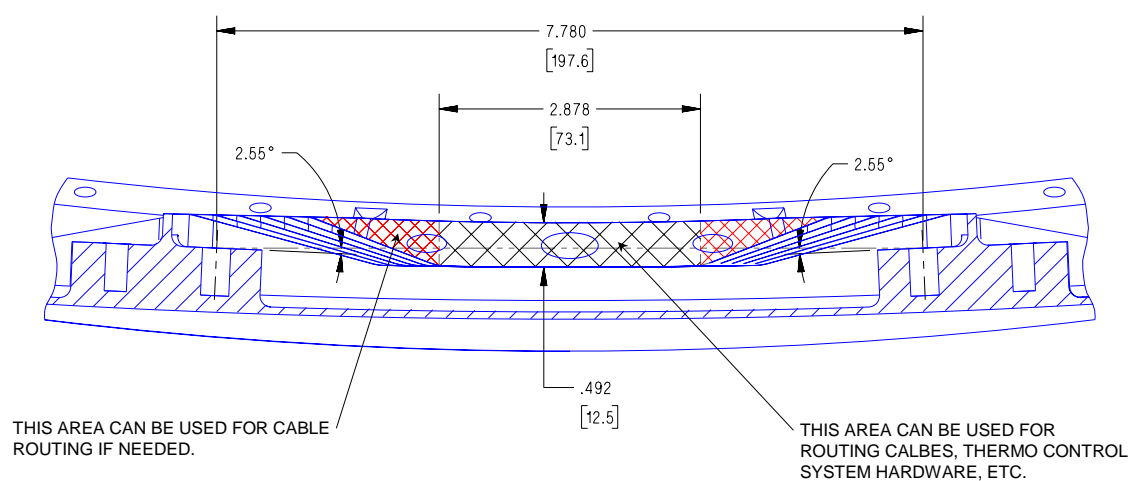


Figure 2.2.11.4-1 ACC PM Mounting Locations



This is a view looking down the conical flange between the ribs based on the section lines shown in Figure 2.2.11.3-1.

Figure 2.2.11.4-2 Keep-In Zone for ACC and Tracker Electrical/Plumbing Lines

2.2.11.5 Thermal Control System Interface to Vacuum Case

The TCS Group shall utilize the generic hole patterns on the upper and lower support rings of the Vacuum Case as input for the design of the TCS interfaces with the VC. All generic hole usage by TCS components shall be coordinated with the Mechanical Integration Team at CERN to ensure that identified TCS interfaces are available and are entered into the hole pattern database table as “reserved”.. See Figures 2.2.11.3-2 through 2.2.11.3-6 for the generic hole pattern. The generic hole pattern as described in this document, in conjunction with the hole database table, shall be the only hole pattern available for the grounding and lacing of the MLI blankets .

2.2.12 Structural Finish and Flatness

All AMS-02 experiment structural interfaces shall have a surface finish of 125 micro-inches or better. Mounting surfaces shall not be painted, but shall be anodized or alodined aluminum. All vacuum sealing surfaces will be cleaned, polished and protected with a thin film of vacuum grease or equivalent.

3.0 ASSEMBLY REQUIREMENTS

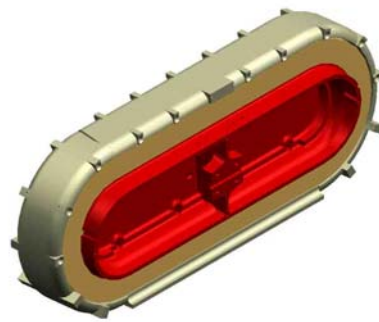
3.1 Assembly Procedure Between VC And Cold Mass

The assembly procedure of the Vacuum Case / Cold Mass (CMR or Flight Magnet) will be performed in England at ETH/SCL facilities. Figure 3.1-1 shows the assembly procedure for the Vacuum Case / Cold Mass.

Figure 3.1-1 VC/Cold Mass Assembly Procedure (shown below)

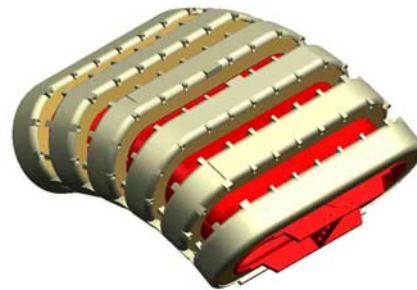
Step 1:

Fabricate and assemble all 12 racetrack coils and test each one individually



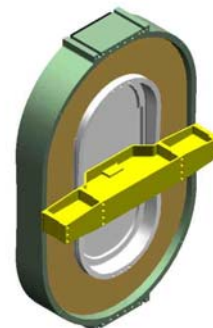
Step 2:

Assemble 6 together, twice. One for each side.



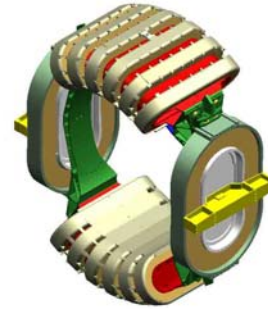
Step 3:

Fabricate and assemble 2 Dipoles and test each one Individually.



Step 4:

Assemble all coils together
Including Racetrack End frames.

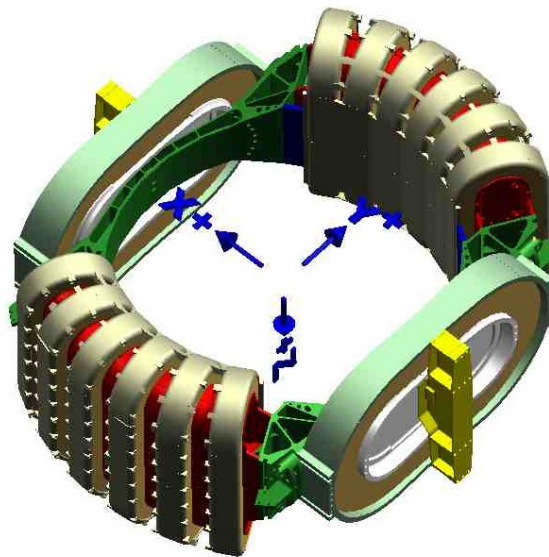


Step 5:

Complete all plumbing, up to helium vessel

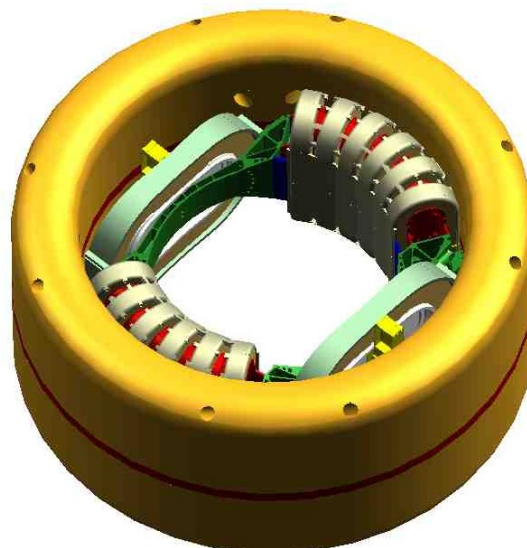
Step 6:

Turn to $-z$ axis upwards



Step 7:

Fit helium vessel and
Connect to coil pipework



Step 8:

Fit cold-warm supports (except warm end item)

Step 9:

Complete all 1.8 K instrumentation (this includes accelerometers on CMR)

Step 10:

Lift cold mass and put in assembly frame inverted ('top' is down).
Transfer loads to four C1W1 supports (only)



Step 11:

Assemble all Pipework, Superinsulation, Radiation Shields, Radiation shield Supports, Current leads, Instrumentation; (access from above and below).

Step 12:

Fit from above the VC Lower Support Ring (shown in green), supported on Assembly Frame, with warm Bods in place (retracted).

Step 13:

Transfer load to 4 C2W2 supports.

Step 14:

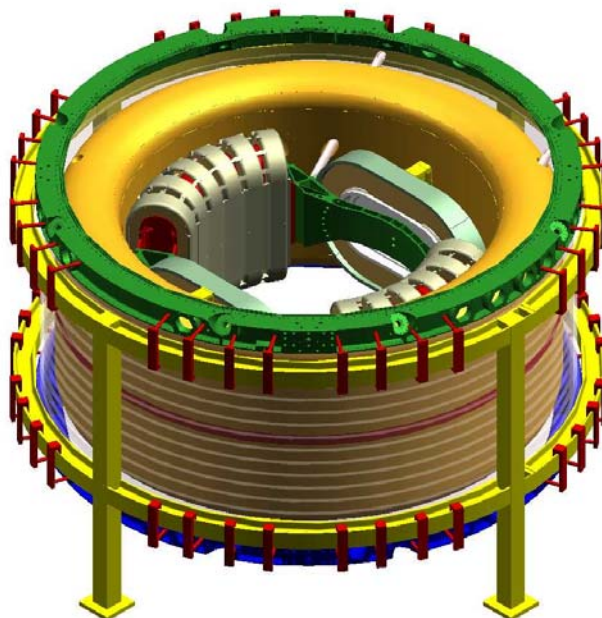
Re-tension 4 C1W1 supports to VC Lower Support Ring.
Complete pipework etc to VC Lower Support Ring.

Step 15:

Lift whole cold mass via the VC Lower Support Ring and install in the pre-assembled (inverted) VC Outer Cylinder / VC Upper Support Ring.

Step 16:

Re-install VC / Cold mass into re-built Assembly Frame to allow tension loads to be reacted so as to retain circularity of VC Upper and Lower Support Rings.



Step 17:

Tension remaining cold to warm supports and complete pipework etc to VC Upper Support Ring.

Step 18:

Set up all CTW straps correctly to tension values based on the cold mass replica (CMR) assembly sequence.

NOTE: During the CMR assembly sequence, the cold mass will have been supported via a load cell to simulate zero g and all supports tensioned to the warm, zero 'g', preload. Load cell is then removed and the resulting tensions in all supports are recorded. These tensions are used during the assembly of the flight article.

Step 19:

Complete all work to internals of VC, fit cryocoolers.

Step 20:

Fit Upper Conical Flange of VC to underside of assembly.

Step 21:

Fit Inner Cylinder of VC.

Step 22:

Fit Lower Conical Flange of VC to top of assembly.

Step 23:

Fit temporary O-ring seal fixtures to Inner Cylinder, perform pressure test and leak test on all systems and operate cryosystem.

Step 24:

Rotate to where the z axis is horizontal and weld the Inner Cylinder to the Conical Flanges.

Step 25:

Pressure test and leak test Vacuum Case.

Step 26:

Complete external pipework and instrumentation.

3.1.1 Hardware

The hardware provided by each group and the description is shown in Table 3.1.1-1.

TABLE 3.1.1-1 PROVIDED HARDWARE SUMMARY TABLE

HARDWARE	PROVIDER	DESCRIPTION
Vacuum Case	ESCG/NASA-JSC	Structural Test Article (STA) and Flight Vacuum Case
Weld Fixture	ESCG/NASA-JSC	Used to support VC during welding of the inner cylinder to conical flange.
Temporary Port Closeout Covers	ESCG/NASA-JSC	Used to temporarily seal the VC (STA and Flight) during ground vacuum leak tests and proof pressure tests prior to the installation of the final closeout port covers or caps. Also used for flight spare ports
Hydra - Set	ESCG/NASA-JSC	Will be on loan to SCL for use in the VC/Cold Mass assembly process.
Plumbing and Electrical Feed Thru Port Covers and Caps, and Support Strap Closeout Caps	SCL/ETH	Used to seal the VC (STA and Flight) during ground vacuum leak tests and proof pressure tests after installation of cryosystem.
Cryocooler Feed Thru Port Covers / Cryocooler Support Bracket-Compliant Mount	ETH/MIT/ NASA-GSFC	Used to support the cryocoolers to the VC, to seal the cryocooler port, and to mechanically & thermally isolate the cryocoolers. Use temporary covers for spare ports.
Cryocoolers	ETH/MIT/ NASA-GSFC	Mount to the Upper and Lower Support Rings on the VC.
Cryocooler Heat Rejection System	TBD	Used to draw the heat away from the cryocooler warm end and distribute it to the AMS-02 Thermal Control System (TCS).
Cold Mass Replica (CMR) Assy.	SCL/ETH	The CMR will match the mass and inertia properties of the flight magnet to within $\pm 5\%$. It will be installed in STA Vacuum Case.
Cold Mass Replica Straps	SCL/ETH	Flight identical non-linear straps to be used with STA VC and CMR. Must be capable of changing these straps to linear response during the modal and static testing of the AMS-02 payload. Details to be discussed.
STA SFHe Tank	SCL/ETH	To be used with STA Vacuum Case & CMR.
Pressure Gauge for the STA Acoustic Test	SCL/ETH	The pressure gauge will be used to check the pressure of the Vacuum Case before, during and after the acoustic test.
STA Cryosystem	SCL/ETH	To be used with STA Vacuum Case & CMR.

TABLE 3.1.1-1 PROVIDED HARDWARE SUMMARY TABLE

HARDWARE	PROVIDER	DESCRIPTION
Cryomagnet	SCL/ETH	To be used with the flight Vacuum Case and Flight SFHe Tank.
Flight SFHe Tank	SCL/ETH	To be used with flight Vacuum Case and Cryomagnet.
Flight Cryosystem	SCL/ETH	To be used with flight VC, flight Cryomagnet, and SFHe Tank
Flight Straps	SCL/ETH	Support the Flight SFHe Tank, the Flight Cryosystem, and the Cryomagnet.
Burst Disks: VC = 0.8 atm SFHe = 3.0 B	SCL/ETH	All burst disks for STA & Flight VC and STA & Flight SFHe will be provided by SCL/ETH as defined by the SCL/ETH cryogenic schematic.
Temporary O-ringed Seal for Inner Cylinder to Conical Flange Interface of VC	SCL/ETH	Will be used with the STA and Flight VC to perform vacuum leak checks. Must be provided to NASA/ESCG to perform this early testing on the VC before the VC arrives in England.
Ground Support Hardware for Magnet / Vacuum Case Assembly	SCL/ETH	-Must be capable of rotating complete magnet system. -Must be capable of maintaining the required shape of the VC during the assembly process.
Cryosystem GSE	SCL/ETH	To be used to support the filling an operations associated with helium or superfluid helium. This hardware will be used in England, Zurich, KSC, wherever the vibration testing occurs, and wherever the thermal vacuum testing occurs.

3.1.2 Strap System

The Strap System is completely designed, built and tested by SCL / ETH. Since the design of this system affects the design of the Vacuum Case, the load versus deflection envelope shown in the following Figures will be adhered to. Any changes to these curves must be agreed to by all parties affected by the change.

Table 3.1.2-1 Non-Linear Strap Load Data

C1W1 Warm					
Nominal		Upper Bound		Lower Bound	
Deflection (in)	Load (lbs)	Deflection (in)	Load (lbs)	Deflection (in)	Load (lbs)
0	0	0	0	0	0
0.6693	1573	0.5512	1573	0.9055	1798
0.8268	2472	0.8268	3146	1.1811	24180
0.8661	3596	0.9055	6742		
0.9055	5843	1.1811	29124		
1.1811	26067				
C2W2 Warm					
Nominal		Upper Bound		Lower Bound	
Deflection (in)	Load (lbs)	Deflection (in)	Load (lbs)	Deflection (in)	Load (lbs)
0	0	0	0	0	0
0.2756	652	0.5512	1573	0.9055	1798
0.6693	1596	0.8268	3146	1.1811	24180
0.8268	2494	0.9055	6742		
0.8661	3618	1.1811	29124		
0.9055	5888				
1.1811	26247				
C1W1 Cold					
Nominal		Upper Bound		Lower Bound	
Deflection (in)	Load (lbs)	Deflection (in)	Load (lbs)	Deflection (in)	Load (lbs)
0	0	0	0	0	0
0.812992126	1797.753	0.5512	1573	0.9055	1798
0.87007874	3146.067	0.8268	3034	0.9449	3303
0.929133858	5393.258	0.9055	5236	1.1811	22472
0.966535433	7865.169	1.1811	27618		
1.029527559	12584.27				
1.080708661	16853.93				
1.1811	25228.84				
C2W2 Cold					
Nominal		Upper Bound		Lower Bound	
Deflection (in)	Load (lbs)	Deflection (in)	Load (lbs)	Deflection (in)	Load (lbs)
0	0	0	0	0	0
0.812992126	1779.069	0.5512	1573	0.9055	1798
0.87007874	3072.351	0.8268	3034	0.9449	3303
0.929133858	5311.167	0.9055	5236	1.1811	22472
0.966535433	7780.119	1.1811	27618		
1.029527559	12497.34				
1.080708661	16736.52				
1.1811	25058.7				

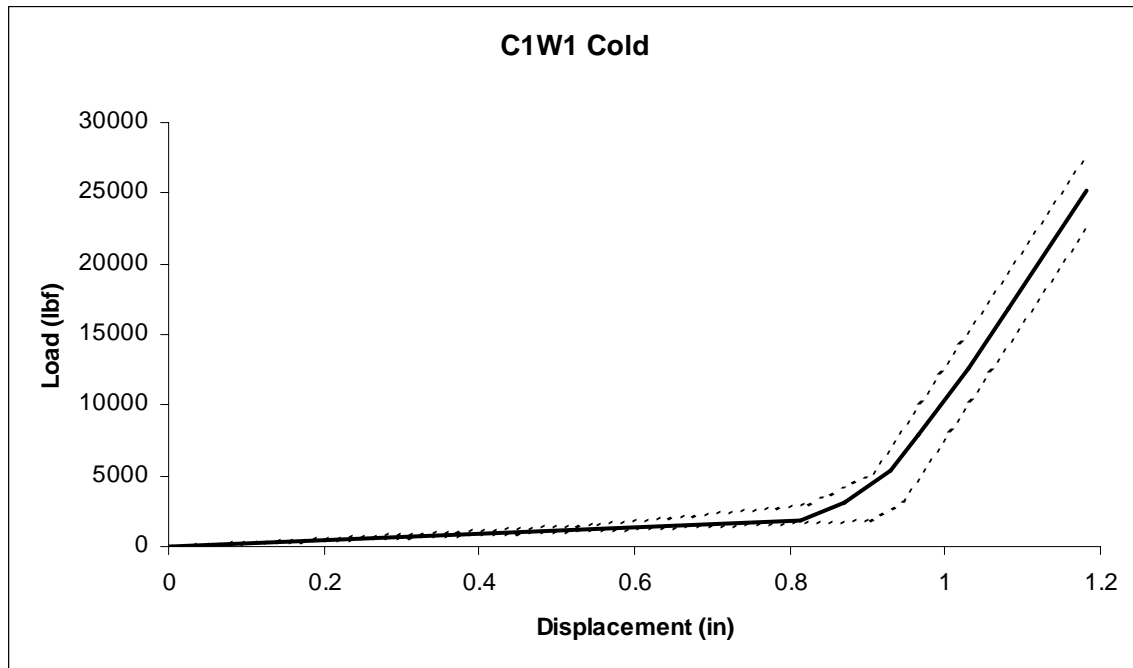


Figure 3.1.2-1 Force Versus Deflection for C1W1 Strap - Cold

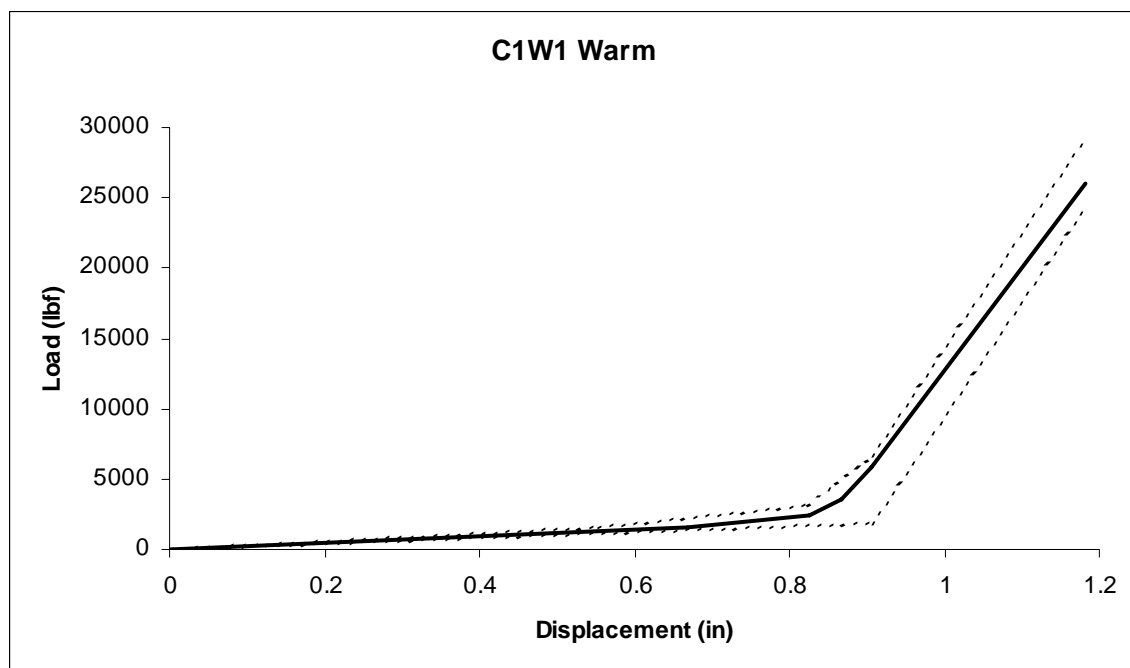


Figure 3.1.2-2 Force Versus Deflection for C1W1 Strap - Warm

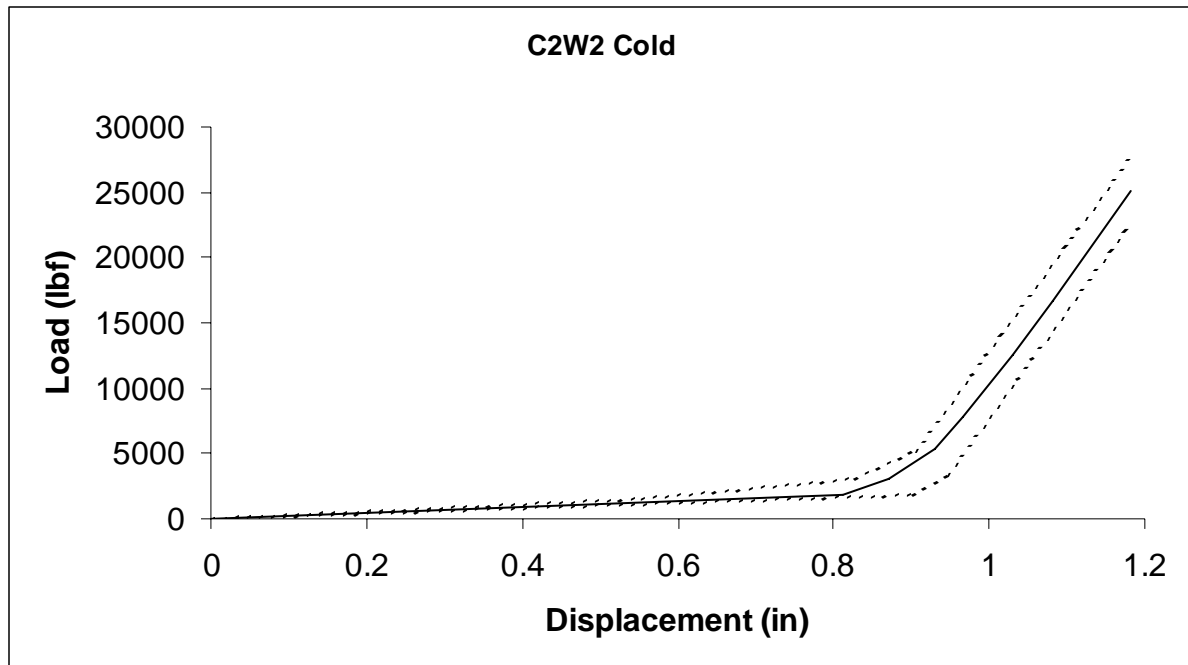


Figure 3.1.2-3 Force Versus Deflection for C2W2 Strap - Cold

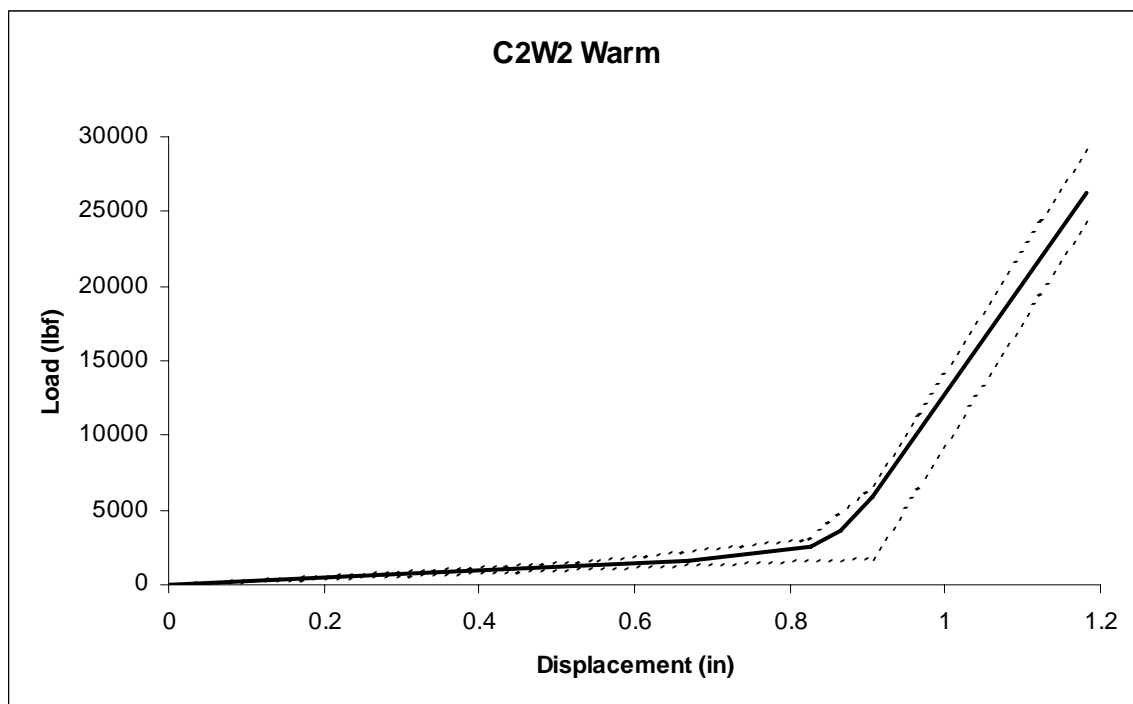


Figure 3.1.2-4 Force Versus Deflection for C2W2 Strap - Warm

3.2 Assembly Procedure Between VC and ACC

The assembly procedure of the Vacuum Case / ACC will be covered in the Integration Plan for the AMS experiment.

3.3 Assembly Procedure Between VC and Tracker

The assembly procedure of the Vacuum Case / Tracker will be covered in the Integration Plan for the AMS experiment.

4.0 VACUUM CASE VACUUM AND PRESSURE TEST REQUIREMENTS

4.1 Vacuum Test Requirements

Both the STA and Flight Vacuum Cases will be vacuum leak checked with the temporary port covers and the temporary inner cylinder to conical flange interface seal (provided by SCL/ETH). The test will be considered successful once it shows that the VCs can hold a vacuum of 1.0×10^{-6} torr. The maximum leak/permeability rate shall be 1.0×10^{-7} std cc/sec and will be determined by using a helium leak detector attached to the vacuum space to measure a rate of helium molecules. This entire process will be listed in a Task Preparation Sheet (TPS) prepared by NASA/ESCG with input from ETH/SCL.

Once the cold mass (CMR or flight magnet) is installed inside the VC, the system will be vacuum leak checked with the final port covers and caps and the temporary inner cylinder to conical flange interface seal. If at this point there is a problem attaining an acceptable vacuum, NASA/ESCG will work with ETH/SCL to ensure that all of the NASA/ESCG seals have been installed properly. This may include checks of these seals through the test ports that have been built into the VCs.

4.2 Proof Pressure Test Requirements

Both the STA and Flight Vacuum Cases will be proof pressure tested as required by JSC-28792 (AMS-02 Structural Verification Plan).